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Synopsis of Biological Data on the Pinfish, *Lagodon rhomboides* (Pisces: Sparidae)

February 1985

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George H. Darcy

February 1985

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Synopsis of Biological Data on the Pinfish, *Lagodon rhomboides* (Pisces: Sparidae)

GEORGE H. DARCY[1]

ABSTRACT

Information on the biology and resources of the pinfish, *Lagodon rhomboides* (Pisces: Sparidae), is compiled, reviewed, and analyzed in the FAO species synopsis style.

INTRODUCTION

The pinfish, *Lagodon rhomboides*, is one of the most common inshore fishes of the southern Atlantic and Gulf of Mexico coasts of the United States and is also common on Campeche Bank off the Yucatan Peninsula, Mexico. It occurs in a wide range of habitats, but reaches peak abundance over vegetated bottoms.

Although not of major commercial importance, the pinfish is a common by-catch of commercial trawling operations and is sometimes marketed as a panfish; it is a quality food fish, though usually small. The pinfish is also used in pet food and as bait. It is one of the most commonly caught recreational species throughout its range and is important to subsistence fishermen. Because of its abundance, the pinfish is frequently mentioned in faunal surveys, environmental studies, and studies of estuarine and nearshore community ecology. It often comprises a major component of community respiration and production and has been shown to influence community structure through its food habits. As prey, the pinfish is an important forage fish for other larger recreational and commercial species. The pinfish is also used extensively in laboratory testing of pesticides and other aquatic pollutants. This synopsis summarizes the most important literature concerning the pinfish.

1 IDENTITY

1.1 Nomenclature

1.11 Valid name

Lagodon rhomboides (Linnaeus, 1766) (Fig. 1).

Pinfish, *Lagodon rhomboides* (Linnaeus, 1766:470) type locality: Charleston, SC. The name comes from the Greek *lagos* (hare) and *odontos* (tooth), referring to the large incisor teeth, and the Greek *rhombos* (rhombus) and *-o* + *eidos* denoting likeness of form, referring to the rhomboidal body shape.

1.12 Objective synonymy

The following synonymy is based on the work of Caldwell (1957):

Sparus rhomboides Linnaeus, 1766
Sargus rhomboides. Valenciennes, *in* Cuvier and Valenciennes, 1830
Lagodon rhomboides. Holbrook, 1855
Diplodus rhomboides. Jordan and Gilbert, 1882
Lagodon rhomboidalis. Goode and Bean, 1886
Salema atkinsoni Fowler, 1940
Lagodon mercatoris Delsman, 1941

1.2 Taxonomy

1.21 Affinities

Suprageneric

Phylum Chordata
Class Osteichthyes
Superorder Acanthopterygii
Order Perciformes
Suborder Percoidei
Family Sparidae

Generic

The genus *Lagodon* Holbrook, 1855, is monotypic; type of the genus is *Sparus rhomboides* Linnaeus, 1766, by subsequent designation of Eigenmann and Hughes, 1887:66 (Caldwell 1957). According to Hildebrand and Schroeder (1928) the essential character of the genus is the skull: Supraoccipital and temporal crests nowhere coalescent; interorbital area not swollen; frontal bone in the interorbital area thin, concave in transverse section; temporal crest low, separated from supraoccipital crest by a flattish area, extending forward on each side of supraoccipital crest to the groove of the premaxillary spines. In addition to skull characteristics, the genus is distinguished by: Mouth with single row of incisor teeth, triangular in anterior aspect above their base, those in anterior part of mouth almost always with a single notch, the posterior ones with or without the notch; several series of rounded molariform teeth behind incisors (Caldwell 1957). The deeply notched incisor teeth distinguish *Lagodon* from all other sparids (Randall and Vergara R. 1978).

Specific

The following species diagnosis of *Lagodon rhomboides* is from Randall and Vergara R. (1978): Body oval and compressed;

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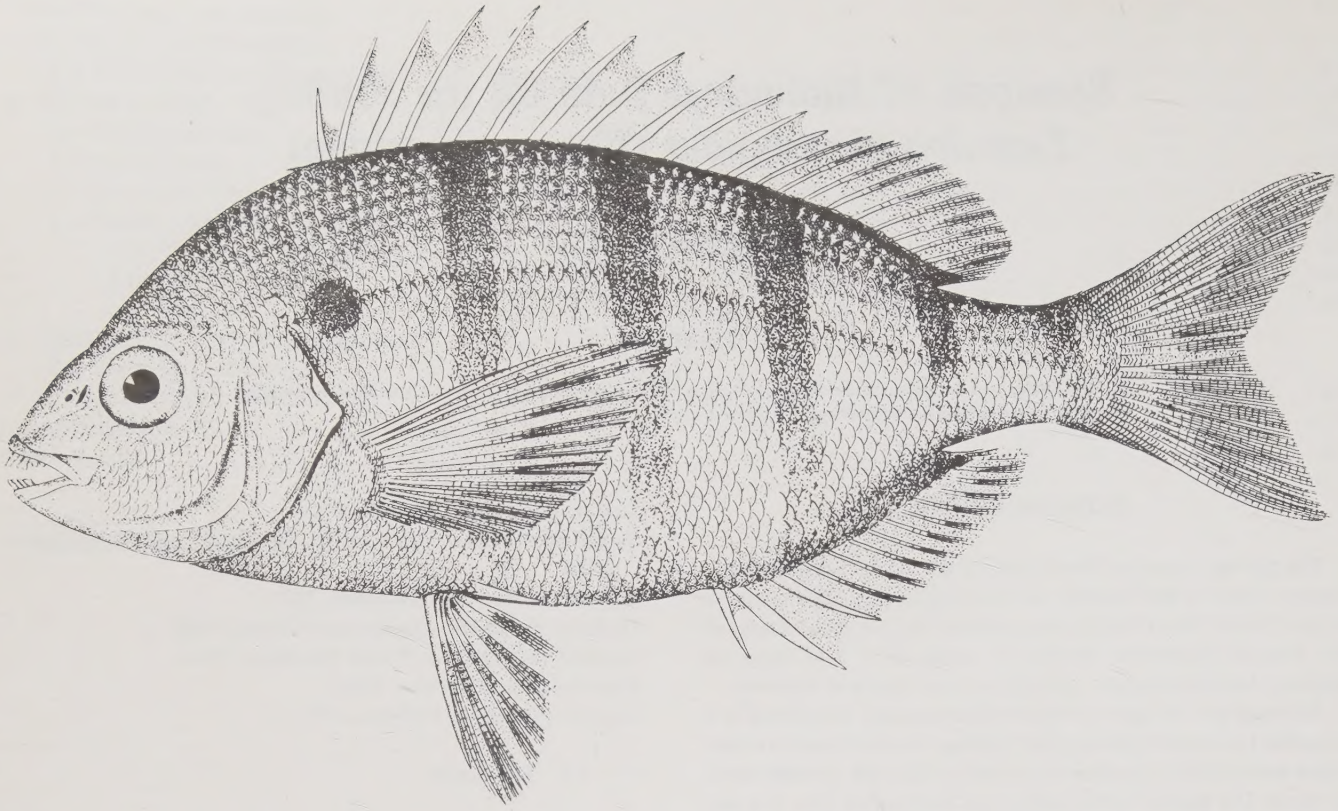

Figure 1.—Adult *Lagodon rhomboides*. (From Goode 1884, Plate 138.)

posterior nostril oval-shaped; mouth comparatively small, the maxilla scarcely reaching to below anterior eye margin; both jaws anteriorly with 8 broad, forward-directed incisorlike teeth, their edges deeply notched; laterally with two and one-half rows of molarlike teeth. Dorsal fin with 12 spines preceded by a small forward-directed spine; usually 12 dorsal and 11 anal soft rays; pectoral fins long, extending to anal opening when appressed; caudal fin forked; scales on lateral line 53 to 68.

1.22 Taxonomic status

Lagodon rhomboides is generally considered a morphospecies.

1.23 Subspecies

No subspecies are recognized. Caldwell (1957) investigated morphometrics and meristics of pinfish and found a remarkable lack of geographic variation. Only the number of lateral line scales varied significantly from place to place, and this Caldwell (1957) attributed to environmental factors, rather than genetic differences. No significant differences were found between specimens taken in deep versus shallow water.

1.24 Standard common names, vernacular names

The generally accepted common name of *L. rhomboides* in the United States is pinfish (Robins et al. 1980), and standard FAO common names are: English, pinfish; French, sar salème; Spanish, sargo salema (Randall and Vergara R. 1978). In Cuba, *L. rhomboides* is called chopa espina (Olaechea and Sauskan 1974). Many other common names exist, some of the most used are: Sailor's choice, bream (especially in the Florida Keys), and chopa spina (Caldwell 1957); local variations include: Fair-maid (Virginia), salt-water bream (South Carolina), piggy-perch (certain parts of the western Gulf of Mexico), sargo (in some areas such as the Florida Keys), and Spanish porgy (Bermuda). Other common names known to have been applied to *L. rhomboides* are: Banded porgy, bastard margaret, brim, Canadian bream, chopa, hogfish, perch, pinfish, pin perch, pigfish, pisswink, porgy, rhomboidal porgy, robin, ronco blanco, ronco prieto, sand perch, sargo, scup, sea bream, shiner, shiny scup, spot, squirrelfish, thorny-back, and yellowtail (Goode 1884; Caldwell 1957; Hoese and Moore 1977).

1.3 Morphology

1.31 External morphology

The following description is based on Jordan and Fesler (1893), Hildebrand and Schroeder (1928), Caldwell (1957), and Johnson (1978) except where otherwise noted. Body oblong, variable in depth, compressed, its depth 2.1-2.3 times in SL; back elevated; head 3.1-3.4 in SL, flattened, profile not very steep; snout rather pointed, 3.2-4.1 in head; eye 1.3-1.5 in snout, 1 in interorbital, 2.7-3.1 in head; interorbital 2.9-3.6 in head; mouth rather small, nearly horizontal, terminal; maxillary 2.9-3.3 in head, not reaching to front of orbit; maxillary slipping under lachrimal for most of its length (Kilby 1955); each jaw with 8 broad, deeply notched incisors anteriorly on edge of jaws, followed by 2 rows of low, broad, blunt teeth; vomer and palatines without teeth; gill rakers short and slender, 6-9 upper, 10-15 lower, usually 7 and 13; branchiostegals 6; scales rather small, firm, ctenoid, extending on base of caudal and forming a scaly sheath on soft part of dorsal and anal fins; lateral line scales 53-68, mean 62; scales between lateral line and dorsal fin origin 10; dorsal fin VIII-XIII, 10-12, usually

XII, 11; anal fin III-IV, 7-12, almost always III, 11; pelvic fins I, 5; pectoral fins 14-17 rays, usually 16; caudal fin with 15 branched rays; dorsal spines all rather long, slender, and extremely sharp; dorsal fin long, continuous, rather low, preceded by an antrorse spine; dorsal fin origin a little in advance of base of pectorals; caudal fin deeply forked; anal fin with 3 rather strong, sharply pointed spines, the second and third of equal length, the soft part of the fin similar to dorsal fin; pelvic fins moderate and broad, inserted behind base of pectorals; pectorals long, pointed, reaching well beyond tips of pelvics and upper rays reaching past origin of anal fin, 2.9-3.5 in SL; vertebrae 10+14 (Eigenmann and Hughes 1887; Miller and Jorgenson 1973).

A table of selected body proportions of pinfish, with means and ranges was presented by Caldwell (1957); with increasing body length, the eye becomes proportionately smaller, the snout longer, the head shorter, and the interorbital distance greater. The mean and range of variation of the relationship of body depth to length remains constant in pinfish 14-328 mm SL (Caldwell 1957). Standard length, total length, and fork length are related as follows:

TL = 1.26 SL; FL = 1.16 SL (Caldwell 1957).

Holbrook (1860) described the internal anatomy of the pinfish, Eigenmann and Hughes (1887) described the skeleton, and Caldwell (1957) and Stoner and Livingston (1984) described and illustrated development of the incisor teeth.

Color of the pinfish has been described by Jordan and Evermann (1896-1900) and Hildebrand and Schroeder (1928): Olivaceous to dark green above, bluish-silvery below; a dark spot on shoulder; 4-6 dark crossbars on sides, varying in distinctness among individuals; sides with several light-blue and yellow longitudinal stripes (fading and nearly disappearing in preservative); dorsal fin plain or pale blue, with faint yellowish-brown spots and with yellowish brown on distal parts of the spinous portion; caudal and pectoral fins pale yellow, caudal sometimes faintly barred; anal fin translucent on basal half, the remainder yellowish brown; pelvics pale, with yellowish-brown streaks at middle of fin. The young are less brightly colored than adults; longitudinal stripes are absent and the dark crossbars quite distinct.

2 DISTRIBUTION

2.1 Total area

The pinfish is distributed in coastal waters from Cape Cod, MA, to Florida, throughout the Gulf of Mexico to the Yucatan Peninsula, Mexico, and in Bermuda (Caldwell 1957; Randall and Vergara R. 1978) (Fig. 2). Records from the Bahamas (Lee 1889), Jamaica (Fowler 1939), and Cuba (Poey 1856-58) are doubtful (Caldwell 1957; Johnson 1978) and may have been based on misidentifications (such as confusion with the sea bream, *Archosargus rhomboidalis*), strays, or imports. A specimen collected at Great Exuma, Bahamas, by Yocum (1971) probably represents a stray. Pinfish appear to cross the Gulf Stream only rarely (Hoese and Moore 1977).

See 2.21, 2.22, and 4.2.

2.2 Differential distribution

2.21 Spawn, larvae, and juveniles

Pinfish eggs are probably planktonic, but have not been identified in the natural state (Caldwell 1957). Eggs are spawned offshore; Hildebrand and Cable (1938) found the smallest pinfish larvae (5.0-10.0 mm TL) about 19.3-20.1 km (12-13 mi) offshore, though the eggs may have been spawned farther offshore than that. Houde et al.[2] collected larval pinfish (2.1-13.0 mm TL) in fall, winter, and spring in the eastern Gulf of Mexico; 97.6% were collected in winter. Larvae were collected at 15°-26°C and 33-36‰. More than 60% of these larvae were taken in < 30 m of water, but larvae were widely distributed over the sampling area, occurring from 7-64 m stations (Fig. 3). Larval abundance was positively correlated with surface salinity and station depth. Franks et al. (1972) reported one pinfish larva from an October bottom sample from off Mississippi at 55.6 m (30 fathoms); whether this represents a normal pattern, a premature metamorphosis, or a sampling artifact, is not known. Near Beaufort, NC, Lewis and Wilkens (1971) found pinfish larvae most common in daylight surface plankton tows and much less abundant in night and bottom tows. Hildebrand and Cables' (1938) specimens were collected in surface tows.

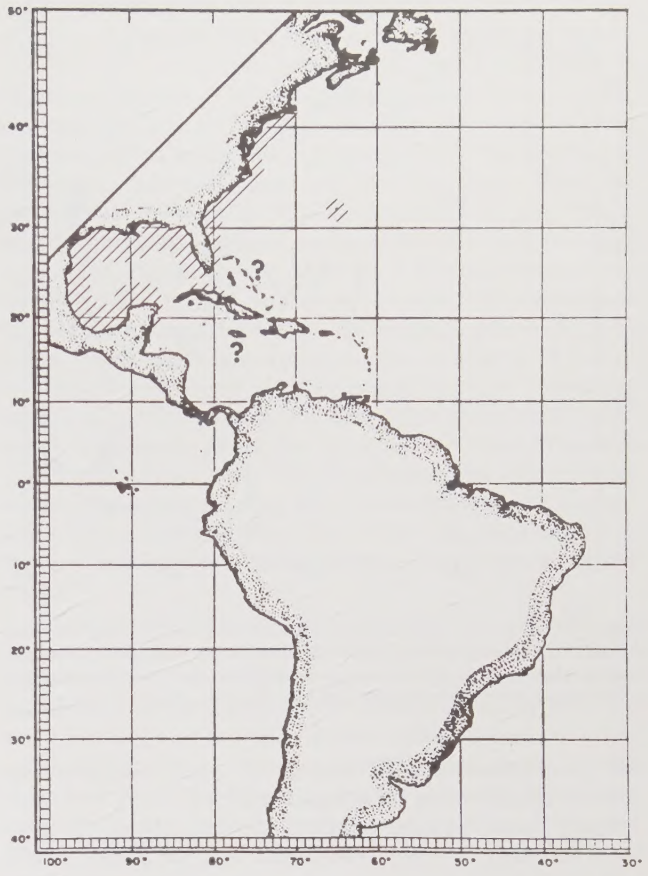

Figure 2.—Distribution of *Lagodon rhomboides*. (Based on Caldwell 1957; Randall and Vergara R. 1978.)

Larvae move inshore before metamorphosing. Many authors have reported the influx of small (approximately 10-12 mm SL) larvae to shallow water in fall, winter, and spring (Table 1). The peak of this movement appears to be in February and March, with

[2]Houde, E. D., J. C. Leak, C. E. Dowd, S. A. Berkeley, and W. J. Richards. 1979. Ichthyoplankton abundance and diversity in the eastern Gulf of Mexico. Report to the Bureau of Land Management under Contract No. AA550-CT7-28, June 1979, 546 p.

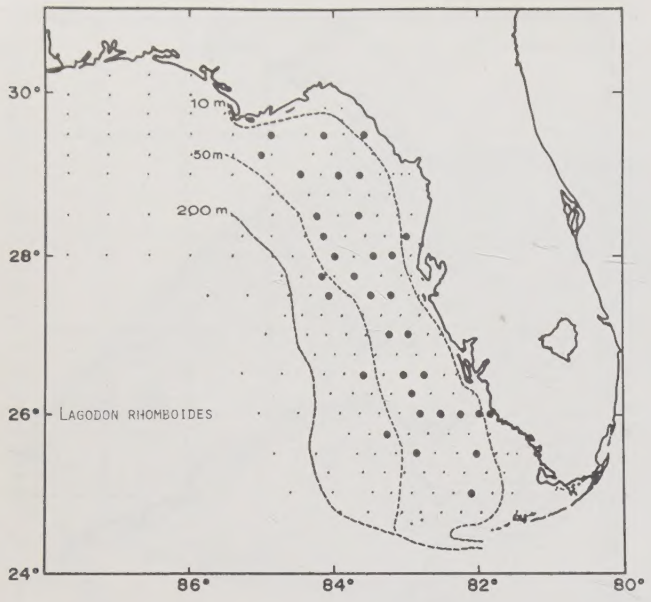

Figure 3.—Stations at which *Lagodon rhomboides* larvae occurred at least once during 17 cruises to the eastern Gulf of Mexico, 1971-74. Large dots indicate stations at which *L. rhomboides* larvae were found. Small dots are stations at which *L. rhomboides* larvae were not collected. (Houde et al., see text footnote 2.)

little geographical variation. Larvae settle on or near the bottom (Hildebrand and Cable 1938; Caldwell 1957).

Newly metamorphosed juveniles of about 12 mm SL were found only along beaches and on shallow flats by Caldwell (1957). Hildebrand and Cable (1938) reported 12 to 16 mm TL young from deeper channels, sounds, and estuaries near Beaufort, in winter, often in large schools with young Atlantic croakers, *Micropogonias undulatus*, and spot, *Leiostomus xanthurus*, of the same size. Small juveniles found over shallow, vegetated bottom are generally less pigmented and shallower bodied than those over vegetated bottom (Hildebrand and Cable 1938; Caldwell 1957). Shenker and Dean (1979) reported that larvae entering North Inlet estuary, SC, were most common in mid-day samples.

Larger juveniles are spread over a wide variety of habitats, mostly inshore, though Hoese (1973) reported many juveniles off the Georgia coast and few inshore. Elsewhere, pinfish juveniles occur over vegetated areas such as eelgrass or turtlegrass flats (Brook 1977; Nelson 1979a, b; Stoner 1979a, 1980a, b, c, 1982; Nelson et al. 1982), and around piers, pilings, and jetties (Hildebrand and Cable 1938; Reid 1954; Hastings 1972; Vick[3]); in canals and river mouths (Wang and Raney 1971; Kinch 1979); and in intertidal pools in salt marshes (Dahlberg 1972). Stoner (1979a) found that juveniles rarely venture beyond seagrass-covered habitats. Hyle (1976) reported juveniles abundant in areas rich in the green alga *Ulva*. Largest juveniles may move to deeper inshore flats and channel edges (Caldwell 1957; Wang and Raney 1971; Weinstein et al. 1977). At the end of their first summer, age-0 pinfish move to deeper water offshore (Grimes and Mountain 1971; Weinstein et al. 1977).

See 2.3 and 4.2.

[3]Vick, N. G. 1964. The marine ichthyofauna of St. Andrew Bay, Florida, and nearshore habitats of the northeastern Gulf of Mexico. Texas A&M Univ. Res. Found., A&M Proj. 286-D, 77 p.

Table 1.—Size and time of year of larval and postlarval *Lagodon rhomboides* entering shallow-water habitats along the coast of the southeastern United States.

Location	Size	Time of year	Reference
Virginia			
Chesapeake Bay	Not specified	spring	Hilldebrand and Schroeder (1928)
North Carolina			
Beaufort	10 mm TL	Oct.-Apr.; peak Dec., Jan.	Hildebrand and Cable (1938)
	Not specified	first appear early Jan.	Adams (1976a)
Newport River estuary	Not specified	Nov.-Apr.; peak Feb., Mar.	Hoss (1974)
South Carolina			
intertidal creek near Georgetown	Not specified	peak Feb., Mar.	Bozeman and Dean (1980)
North Inlet estuary	10.5-15.5 mm SL	January	Shenker and Dean (1979)
Florida			
northern Florida Bay	10 mm	Mar.-Apr.	Tabb and Manning (1961)
Charlotte Harbor estuary	Not specified	early Feb.	Wang and Raney (1971)
Tampa Bay	Not specified	first appear Dec.	Springer and Woodburn (1960)
Crystal River	12-14 mm SL	first appear Dec.	Grimes and Mountain (1971)
Cedar Key	10-20 mm SL	first appear late Nov.	Reid (1954)
	13-20 mm SL	first appear Jan.	Kilby (1955)
	11 mm SL	first appear Dec.	Caldwell (1957)
Panhandle salt marshes	11+ mm SL	spring	Subrahmanyam and Drake (1975)
St. Andrew Bay jetties	11 mm SL	Dec.-Apr.	Hastings (1972)
Alabama			
mouth of Mobile Bay, Perdido Bay	8-21 mm TL	Dec.-Apr.	Swingle (1971)
Mississippi			
plankton samples from passes	11-18 mm TL	Dec.-Mar.	Franks et al. (1972)
Texas			
Texas coast	13 mm TL	Jan.-Mar.	Gunter (1945)
Galveston I.	Not specified	Jan.-Apr.; peak Feb.	Arnold et al. (1960)
Redfish Bay	15 mm (measurement unspecified)	Feb.-May; peak Apr.	Hoese and Jones (1963)
Upper Laguna Madre	25 mm SL	Mar.-Apr.	Hellier (1962)

2.22 Adults

Adult pinfish occupy a variety of habitats, both inshore and offshore. In shallow water they occur over vegetated flats, in mangrove areas, over rocky substrates, and around wharves, pilings, and jetties (Reid 1954; Kilby 1955; Cameron 1969a; Hastings 1972; Hoese and Moore 1977; Randall and Vergara R. 1978; Vick footnote 3); in canals, ponds, and creeks in salt marshes (Zilberberg 1966; Swingle 1971; Dahlberg 1972; Subrahmanyam and Drake 1975; Cain and Dean 1976; Kinch 1979; Shenker and Dean 1979; Weinstein 1979; Bozeman and Dean 1980; Crabtree and Dean 1982); and occasionally over sandy bottoms and along beaches (Reid 1954; Caldwell 1957; Springer and Woodburn 1960; Modde and Ross 1980). Large individuals often occupy deeper inshore habitats such as channels and passes (Caldwell 1957; Hellier 1962; Wang and Raney 1971). Protected waters are generally preferred.

Pinfish also occur offshore, particularly in the cooler months of the year. Struhsaker (1969) reported them very common (> 50% occurrence) in coastal, open-shelf, and live-bottom areas off the southeastern Atlantic coast of the United States. Pinfish were not trawled commonly during MARMAP surveys of the South Atlantic Bight (Wenner et al. 1979), but mostly sand bottom was sampled. Barans and Burrell (1976) and Miller and Richards (1980) also reported pinfish from offshore waters of the southeastern United States.

In the Gulf of Mexico, Franks et al. (1972) trawled pinfish off the Mississippi coast in every month of the year except April, and found the greatest concentrations at 54.9-91.5 m (30-50 fathoms). Pinfish move offshore in the cooler months along the northern Gulf coast (Hastings 1972); Springer and Bullis (1957) and Bullis and Thompson (1965) reported pinfish catches offshore, particularly in winter. Results of trawling on the West Florida Shelf reported by Darcy and Gutherz (1984) indicated that pinfish are most common in depths < 36 m, particularly between Tampa Bay and the Dry Tortugas. Pinfish are also common on brown shrimp grounds in the northwestern Gulf in winter, but not common on white shrimp grounds (Hildebrand 1954; Chittenden and McEachran 1976); pinfish were trawled as deep as 73.2 m (40 fathoms) on shrimp grounds. Hastings (1972), Hastings et al. (1976), and Stott et al. (1980, 1981) reported pinfish from offshore platforms in the northern Gulf.

On Campeche Bank, pinfish are trawled at least as deep as 50 m, with greatest concentrations encountered on the central Bank at 30-50 m (Sokolova 1965; Kapote 1971; Sauskan and Olaechea 1974).

See 2.3 and 4.2.

2.3 Determinants of distribution changes

Distribution of pinfish is determined by temperature (season), salinity, bottom type and vegetation, water clarity, and growth stage of the individual. The relative importance of these factors in determining distribution is not clear; conflicting conclusions appear in the literature, though season is the most commonly mentioned factor.

Seasonal changes in distribution of pinfish have been reported by many authors working throughout the geographical range of the species. Roessler (1970) concluded that abundance of pinfish in Buttonwood Canal, FL, correlated best with season. Pinfish usually move to deeper water during the coldest part of the year. Numerous authors (e.g., Cain and Dean 1976; Nelson 1979b; Stoner 1979a, 1980a; Orth and Heck 1980; Stoner and Livingston 1984) have noted decreased abundance of pinfish in shallow water in the winter. This movement may be offshore (Gunter 1945; Joseph and Yerger 1956; Grimes and Mountain 1971; Ogren and Brusher 1977), or into deeper inshore waters such as channels and basins (Tabb and Manning 1961; Hellier 1962; Cameron 1969a). Such movements are probably attempts to avoid low water temperatures; spawning also takes place during this period. Abruzzini et al. (1979, 1982) and Clem et al. (1981) found that the immunity system of pinfish is related to temperature of acclimation. Pinfish also sometimes move to slightly deeper water in the warmest months of summer to avoid high temperatures (Cameron 1969a; Adams 1976a). By moving to somewhat cooler water, pinfish may regulate their metabolism (Adams 1976a).

Although pinfish are usually reported to move offshore in winter, some individuals may remain in nearshore waters year-round (Hildebrand and Cable 1938; Springer and Woodburn 1960; Swingle 1971; Hyle 1976; Modde and Ross 1980). Winter inshore populations are often much smaller than summer populations, however (Gunter 1945; Reid 1954; Cain and Dean 1976; Nelson 1979b; Stoner 1979a, 1980a; Stoner and Livingston 1984).

Pinfish are found through a wide range of salinity, from $0^0/_{00}$ to well over $40^0/_{00}$. Several authors, such as Gunter (1945), Kilby (1955), and Weinstein (1979), reported that pinfish are rather indifferent to salinity, and that other factors such as vegetation are more important in determining distribution. Others, however, noted salinity effects. Cameron (1969a) reported that pinfish abundance on shallow flats along the Texas coast decreased after periods of heavy rain and lowered salinity ($4^0/_{00}$). Wang and Raney (1971) similarly found that juvenile pinfish left river mouths near the Charlotte Harbor estuary, FL, when heavy July rains lowered salinity. Subrahmanyam and Drake (1975) concluded that pinfish abundance in salt marshes of the Florida Panhandle was correlated with salinity rather than temperature, and Subrahmanyam and Coultas (1980) found a positive correlation between salinity and pinfish abundance. At Bayport, FL, over half of the pinfish collected by Kilby (1955) were taken at $5\text{-}10^0/_{00}$, whereas Franks (1970) found pinfish most abundant at Horn Island, MS, at salinities above $18^0/_{00}$. At deeper stations (54.9-91.5 m; 30-50 fathoms) off Mississippi, pinfish were most abundant at $23.0\text{-}37.9^0/_{00}$ (Franks et al. 1972). Although Gunter (1945) found no correlation of fish size with salinity, Wang and Raney (1971) stated that juveniles were more common in low salinity areas than were adults. Stoner and Livingston (1984) reported pinfish most abundant near freshwater inflows to Apalachee Bay, FL. Larvae collected by Houde et al. (see footnote 2) in the eastern Gulf of Mexico were taken in water of $33\text{-}36^0/_{00}$.

Although pinfish occur over many bottom types—mud, coral, sand, rock, and combinations (Caldwell 1957)—there is a preference for vegetated bottom. Kilby (1955) found distribution and density more dependent on vegetation than salinity. Similarly, Caldwell (1957) reported that pinfish avoid exposed coasts, and that the environmental characteristic most influencing local distribution is vegetation. Schwartz (1964) found pinfish more commonly on sandy vegetated bottom than in other habitats. When vegetated areas are not available, or as a secondary center of abundance, pinfish will also live around rocks, jetties, pilings, docks, breakwaters, and mangrove roots (Caldwell 1957). Preference for vegetated bottoms is probably due to the importance of these areas as feeding grounds. Pinfish may congregate in areas near food sources (Hansen 1970); Stoner (1980b) found a high correlation ($r = 0.998, P < 0.01$) between pinfish abundance and macrophyte biomass. Little is known about offshore habitat

preference, though pinfish seem to be more common on live bottom than over sand. Postlarvae are often associated with drifting plant material (Caldwell 1957), probably for protection.

Water clarity may influence local distribution of pinfish—Hoese and Moore (1977) noted that pinfish avoid highly turbid waters off western Louisiana. It is possible that the movements of pinfish away from shallow inshore areas after heavy rains noted by Cameron (1969a) and Wang and Raney (1971) were due, at least in part, to increased turbidity.

Distribution of pinfish also varies with growth stage. Small larvae are pelagic and have been found about 20 km offshore (Hildebrand and Cable 1938). Before metamorphosing, larvae move inshore. During the warmer part of the year, smaller fish (primarily juveniles) usually occupy shallower water than large fish (Caldwell 1957). Tabb and Manning (1961) reported that the smallest fish in northern Florida Bay, FL, occupy the shallowest water during summer. Hellier (1962) found that larger pinfish in Upper Laguna Madre, TX, moved to deeper water such as channels and basins, where some of them remained year-round. Off Tampa Bay, FL, Moe and Martin (1965) found large pinfish (probably age I or older) in fairly deep water (10 m; 6 fathoms) in December; these fish may have been preparing to spawn. Wang and Raney (1971) reported small pinfish (<100 mm SL) common in brackish water in bays, whereas larger individuals were more common in deeper passes. Cameron (1969a) hypothesized that differential depth distribution with size might be due to a difference in prey-size selection, or to the inability of larger pinfish to cope with metabolic extremes of very shallow water.

See 3.16, 3.32, 3.51, 4.2, and 4.6.

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.11 Sexuality

No sexual dimorphism in body shape or color has been reported in pinfish. Sexes are separate and there is no evidence of sex reversals or hermaphroditism.

3.12 Maturity

The smallest specimen of pinfish with developing gonads collected by Caldwell (1957) at Cedar Key, FL, was a 146 mm SL female taken in October. Hansen (1970) found much smaller ripe individuals at Pensacola, FL, and concluded that maturation size was about 80 mm SL. According to Hansen (1970), some age-0 and all age-I individuals were mature, but Caldwell (1957) stated that only age-II and older fish were mature.

3.13 Mating

No records of mating in pinfish were found in the literature. Pairing probably does not take place.

3.14 Fertilization

Fertilization is probably external with eggs and sperm liberated simultaneously.

3.15 Gonads

Gonads are paired and lie immediately dorsal to the intestine in the body cavity, between the lobes of the liver; the gonads are attached anteriorly with mesenteries near the origin of the liver lobes (Caldwell 1957). When ripe, testes are pinkish to flesh-colored or white and slightly distended, and ovaries are yellow with the opaque eggs macroscopically visible (Hansen 1970).

Pinfish ovarian follicles have been cultured in external media (Hall and Cardeilhac 1981). Ovarian follicles of pinfish consist of two distinct types of cells, based on differential staining (Wiley and Cardeilhac 1977). Mammalian pituitary luteinizing hormone and sex hormones have been successfully used to induce oocyte maturation in females (Wiley and Cardeilhac 1977); methyl testosterone injections have been used to obtain ripe sperm from males (Cardeilhac 1981). Exposure to copper levels of 5 ppm had no observable effect on ovarian follicle development (Cardeilhac 1981).

3.16 Spawning

Spawning takes place from late fall to late spring and occurs somewhat offshore. The time of spawning may vary geographically.

Along the southern Atlantic coast of the United States, Hildebrand and Schroeder (1928) and Hildebrand and Cable (1938) reported that pinfish spawn from October to March in the vicinity of Chesapeake Bay. No ripe individuals were collected in the Bay, but the presence of larvae (<10 mm TL) 19-21 km (12-13 mi) offshore indicated that spawning occurred at least that far from shore. Thayer et al. (1974) and Hoss (1974) reported pinfish larvae present in the Newport River estuary, NC, during all months from November to April, with peaks of abundance in February and March; larvae entering the estuary were probably spawned offshore. In the St. Lucie estuary, FL, Gunter and Hall (1963) found smallest specimens in May and hypothesized a winter-spring spawning.

In the Gulf of Mexico, numerous authors have reported fall-winter-spring spawning of pinfish based on larval occurrence. Caldwell (1957) found that postlarvae (11-12 mm SL) first appeared inshore at Cedar Key, FL, in early December and continued to be taken at that size until late April. Joseph and Yerger (1956) reported 17 mm SL juveniles at Alligator Harbor, FL, in late May through July, although Caldwell (1957) questioned the lateness in season of this record. Stoner and Livingston (1984) found smallest specimens (11 mm SL) in December and January in Apalachee Bay, FL. Other workers (Gunter 1945, Texas coast; Reid 1954, Cedar Key, FL; Springer and Woodburn 1960, Tampa Bay, FL; Arnold et al. 1960, Galveston, TX; Tabb and Manning 1961, northern Florida Bay, FL; Grimes and Mountain 1971, Crystal River, FL; Hastings 1972, St. Andrew Bay, FL) have confirmed late fall to late spring spawning. Females collected by Stott et al. (1981) off Louisiana had a predominance of secondary ova in May-June. Males (Stott et al. 1980) collected in the same months had spermatogonia and primary spermatocytes in about equal numbers. Juárez (1975) reported winter and spring spawning on Campeche Bank, stating that pinfish prefer to spawn when waters cool.

Ripe adults have been found offshore. Schools of 1,000-2,000 ripe individuals were reported at the surface off the Mississippi coast over 38 m (21 fathoms) of water in September by Springer (1957). Franks et al. (1972) also found ripe adults off the Mississippi coast in 93 m (50 fathoms) in March. An ichthyoplankton survey in the eastern Gulf of Mexico by Houde et al. (footnote 2) produced pinfish larvae offshore in fall, winter, and spring, with 97.6% of the larvae collected in winter.

See 2.21.

3.17 Spawn

Ovarian eggs measured by Hansen (1970) were 0.09-0.66 mm in diameter (mean 0.38 mm) and opaque yellow. Mature, unfertilized ova examined by Schimmel (1977) were clear, spherical, and 0.90-0.93 mm in diameter. Cardeilhac (1976) reported mature, unfertilized ova of 0.99-1.05 mm (mean 1.02 mm). The eggs are assumed to be pelagic (Caldwell 1957).

3.2 Preadult phase

3.21 Embryonic phase

Artificially fertilized pinfish eggs were reared in the laboratory by Cardeilhac (1976). Seventy-five percent of the fertilized eggs reached the early blastula stage in about 3 h. At 6 h after fertilization, expanding blastulae were visible. By 16 h, the late gastrula stage had been reached and the embryonic axis was evident. Optic cups and lenses were present at 23 h. Heartbeat and body twitching were visible at 27 h. Most eggs hatched in about 48 h at 18°C. Schimmel (1977) also reported there was hatching in about 48 h at 18°C, with the emerging larva 2.3 mm TL. At hatching, the embryo lacks eye pigmentation but has a characteristic melanophore on both lateral surfaces of the body, about 1 mm from the tip of the tail.

3.22 Larvae and adolescent phase

Descriptions of early larval stages of pinfish are based on laboratory rearings. Cardeilhac (1976) reported 50% yolk utilization within 15 h of hatching. Melanophores on the lateral body surfaces disappear within 48 h of hatching, and eye pigmentation develops (Schimmel 1977). Yolk absorption is complete by the time the larva reaches 2.7 mm TL (Schimmel 1977). By 96 h, the larva has attained 2.9 mm TL and the jaw apparatus has developed extensively (Schimmel 1977).

The following larval descriptions are derived from Hildebrand and Cable (1938).

5.0-5.5 mm TL (Fig. 4A)

Body elongate, compressed, depth 3.6-3.9 in SL; dorsal outline concave in advance of eyes and at nape, or just posterior to the brain; head rather low, compressed, 2.9-3.0 in SL; snout moderately pointed, as long as eye, 3.0-3.5 in head; maxillary reaches nearly opposite anterior margin of pupil; gape anteriorly very slightly below level of the middle of the eye; teeth not evident; about 22 myomeres countable; vent slightly nearer base of caudal than tip of snout; primitive dorsal fin membrane in 5.0 mm fish has suggestions of rays which are better developed in 5.5 mm specimens; rays somewhat more definitely developed in anal fin than dorsal; notochord bent upward posteriorly, with well-developed caudal rays below it, the rays broken distally; caudal fin probably rounded; pectoral fins quite well developed and long; pelvics minute. Color pale; three dark spots on median ventral line, one near isthmus, another on chest, third just in advance of vent; row of black dots along ventral outline from origin of anal fin to base of caudal; dark internal area visible on side above and slightly posterior to vent.

6.0-7.0 TL (Fig. 4B)

Body slightly more elongate, depth 3.8-4.0 in SL; concavities in dorsal outline less distinct; about 12 soft rays visible in dorsal and anal fins; fin spines not well differentiated; pectoral fins long, reaching to vent; pelvics scarcely differentiated.

Black dots present in smaller fish persist and are more definite; a few to several black dots present on base of caudal, two or more on upper surface of caudal peduncle, one at nape, and usually an elongate blackish one above the base of the pectoral.

8.0-10 mm TL (Fig. 4A)

Body somewhat more slender, depth 4.3-4.6 times in SL; dorsal outline remains as in smaller fish, but depressions in advance of eyes and at nape have disappeared; brain visible; head 3.5-3.6 times in SL; eye 2.9-3.1 in head; snout 3.0-3.3 in head; mouth oblique, maxillary reaching nearly opposite anterior margin of pupil; jaw teeth evident; no spines evident on preopercular margin; vent at midbody; spines in dorsal and anal fins well differentiated; caudal fin long and rounded, nearly as long as head; pectoral fins long, reaching vent; pelvic fins minute, scarcely longer than pupil.

Additional dark dots along ventral outline of chest and abdomen present, varying in number among individuals; some with a few extra chromatophores on dorsal surface of head.

13-15 mm TL

No measurable changes in body proportions; snout has decreased in proportionate length and is shorter than eye, 3.6-4.0 in head; eye 2.8-3.0 in head; mouth oblique, gape anteriorly only slightly below level of middle of eye; maxillary reaches only slightly beyond anterior margin of eye; teeth minute; skull transparent, brain visible from above; rays in dorsal and anal fins developed in adult numbers, spines remain proportionately much shorter than in adult; caudal fin becomes square when fish attains about 12 mm TL, and is concave at a length of about 14 mm TL; pectorals long, reaching nearly to origin of anal fin; pelvics much larger, nearly as long as eye in 15 mm fish, but spine not yet well differentiated.

Color unchanged from 8.0-10 mm TL specimens.

18-20 mm TL (Fig. 4B)

Variable in shape and color, some 20 mm TL fish remaining as slender as 15 mm TL fish, others deeper; slender specimens pigmented like 15 mm TL fish, deeper bodied specimens much more densely pigmented, with crossbars as in adults; pigmentation and body deepening occur simultaneously but at varying lengths, apparently associated with a change in habitat, body depth 4.3-4.5 in SL in unpigmented specimens, 3.5-3.9 in SL in pigmented specimens; head 3.3-3.6 in SL; eye 2.8-3.2 in head; snout 3.3-3.8 in head; teeth small; pigmented specimens about 20 mm in length at least partially scaled, smaller specimens and unpigmented specimens unscaled; scales ctenoid when present; fins longer and more fully developed in pigmented fish; pelvic spine differentiated; pigmented specimens have first soft ray of pelvics produced into short filament, not present in unpigmented fish; caudal deeply concave.

Unpigmented specimens retain a few dark markings as in smaller specimens; pigmented specimens greenish in life; preser-

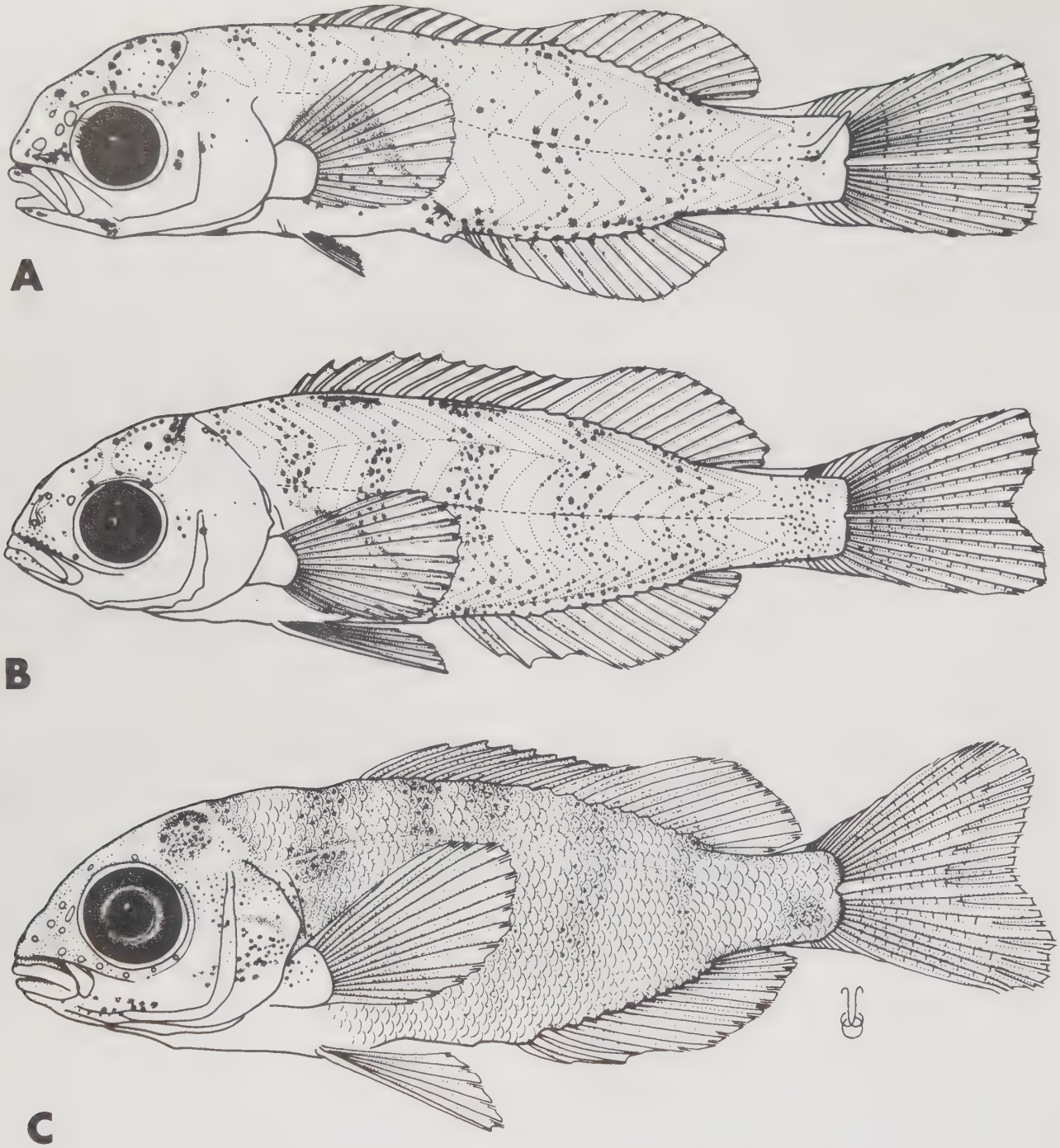

Figure 4.—Larval and juvenile *Lagodon rhomboides*. A. 8 mm TL; B. 16 mm TL; C. 21 mm TL.

ved specimens profusely dotted with black forming crossbars extending more or less on dorsal and anal fins.

21-30 mm TL (Figs. 4C, 5A)

Body strongly compressed, depth 2.5-3.0 in SL (similar to adult); dorsal profile strongly elevated and round, much more strongly curved than ventral outline; head short and deep, 2.8-3.1 in SL; snout blunter and proportionately shorter than in adult, 3.5-3.8 in head; eye 3.1-3.5 in head; mouth almost horizontal, gape entirely below eye; maxillary reaches slightly past anterior margin of eye; anterior teeth somewhat enlarged, exposed tips of anterior teeth pointed and arising in pairs from a common base; body fully scaled; pectorals and pelvics shorter than in adults; first soft ray of pelvic retains a filament which reaches the origin of the anal fin; second anal spine stronger than third, though not as much so as in adult.

General color pattern resembles adult.

≥40 mm TL (Fig. 5B)

Body depth variable, often deeper in smaller fish; snout becoming more pointed and proportionately longer with age (3.1 in head in 40 mm fish, 2.5 in head in 165 mm fish); mouth horizontal and

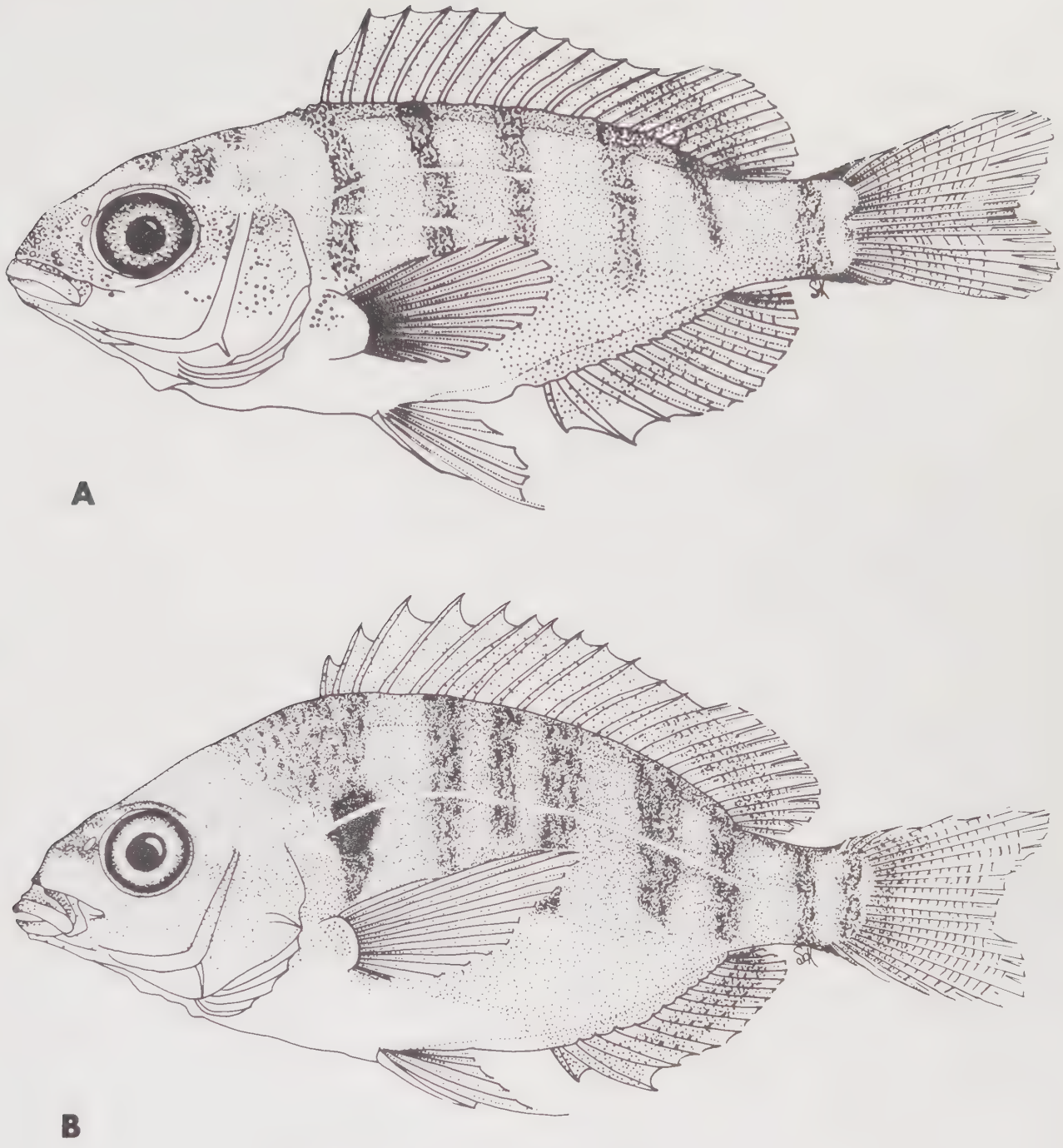

Figure 5.—Juvenile *Lagodon rhomboides*. A. 27 mm TL; B. 63 mm TL.

much below eye; teeth broad and well notched; caudal fin more deeply forked with age, the lobes sharply pointed; pectoral and pelvic fins increase in length and become more pointed; pectorals reach to vent in 40 mm fish, beyond anal fin origin in larger fish; specimens to 100 mm retain filament on first soft ray of pelvic, missing in larger fish; second anal spine thickens with age.

Color extremely variable; dark crossbars present in varying intensity; some specimens with prominent alternating bluish- and yellowish-green longitudinal lines.

Caldwell (1957) described the coloration of 16-17 mm SL postlarvae from Cedar Key, FL: Dorsal and anal fin membranes tipped with brick red, smeared to the base of the fins, particularly so on the spinous portions (and especially so on the spinous dorsal); lemon yellow to orange chromatophores over most of the body, concentrated where the black chromatophores are least numerous; black humeral spot developed; eye iridescent, bluish.

3.3 Adult phase

3.31 Longevity

Pinfish reach a length of at least 437 mm TL (Simmons 1957, Upper Laguna Madre, TX), and are common to 180 mm SL (Randall and Vergara R. 1978). Although Caldwell (1957) estimated

that his largest specimen (328 mm SL) from Cedar Key, FL, was at least 7 yr old, Hansen (1970) stated that few individuals live more than 3 yr, and few age-II fish live to reenter shallow water.

See 4.13.

3.32 Hardiness

The pinfish is a warm-temperate species with a fairly broad range of temperature tolerance. Several authors (Storey and Gudger 1936; Storey 1937; Hildebrand and Cable 1938) have remarked on the ability of pinfish to withstand cold better than most other species living in the same areas. Although some pinfish may overwinter in shallow water (Hildebrand and Cable 1938), most appear to move to deeper water in the coldest months (Gunter 1945; Joseph and Yerger 1956); some individuals may bury themselves in the bottom to avoid extreme cold (T. R. Hellier, pers. commun, as cited in Moore 1976). Cameron (1969b) placed the lower lethal temperature of pinfish at 6°-8°C, though several occurrences of the species in or below that range have been reported. Large numbers of pinfish were killed by cold at Port Aransas, TX, in January 1940 (Gunter 1941), and some were swimming dazed in 4.7°C water. Hellier (1962) collected specimens at temperatures as low as 7.6°C in Upper Laguna Madre, TX, and Hyle (1976) found pinfish at 5.0°C in the Newport River estuary, NC. Moore (1976) reported that although a few torpid individuals were found, no dead pinfish were seen following a cold front (4.0°-7.0°C water) along the Texas coast. In contrast, Gilmore et al. (1978) noted a few specimens killed by cold (10.6°C) at Sanibel Island, FL, in January 1977. In Indian River Lagoon, FL, active schools of pinfish were observed at 10°C (Gilmore et al. 1978). Differences in acclimation may account for the variation in lower lethal temperature reported. Abruzzini et al. (1979, 1982) and Clem et al. (1981) found that the immunity system of pinfish is affected by acclimation temperature. In the laboratory, Peters et al. (1976) found that postlarvae maintained at 6°C stopped feeding after several days, followed by mortality, whereas at 8°C they survived and gained weight.

An upper thermal tolerance of 33°-34°C has been reported for pinfish (Cameron 1969b); temperatures of 35°C or more are actively avoided. Gunter (1945) collected specimens at temperatures as high as 34.9°C along the Texas coast, and Caldwell (1957) collected pinfish at 36.9°C at Cedar Key, FL, though Caldwell's temperature readings were taken at the surface and may have been somewhat higher than those at which the fish were actually living. Franks et al. (1972) stated that pinfish prefer water of 16.0°-27.9°C off the Mississippi coast. In the laboratory, Hoss et al. (1971) determined the average critical maximum temperature for pinfish to be 31.0°C for acclimation at 15°C and $30^0/_{00}$. Chamberlain and Strawn (1977) reported that pinfish began dying at 36.0°C in power plant effluent at Cedar Bayou, TX. Size-temperature interactions indicate that large individuals are less tolerant of high temperatures than small individuals, due to their higher oxygen-consumption rate (Wohlschlag and Cech 1970).

Pinfish are tolerant of a wide range of salinity. They have frequently been reported at very low salinities (Gunter 1945, 2.1-37.2$^0/_{00}$, Texas coast; Tagatz and Dudley 1961, 0-36.9$^0/_{00}$, North Carolina coast; Gunter and Hall 1963, <1.0-14.0$^0/_{00}$, St. Lucie estuary, FL; Perret et al. 1971, 0-30$^0/_{00}$, Louisiana estuaries; Swingle 1971, >2.0$^0/_{00}$, Alabama coast; Dunham 1972, 2.9-26.5$^0/_{00}$, Barataria Bay, LA; Perret and Caillouet 1974, 2.1-11.9$^0/_{00}$, Vermilion Bay, LA; Tarver and Savoie 1976, 0.0-4.9$^0/_{00}$, Lake Pontchartrain, LA) and have been found in freshwater at Homosassa Springs, FL (Gunter 1942; Herald and Strickland 1950) and in the St. Johns River, FL (McClane, pers. commun., as cited in Caldwell 1957). Pinfish in power plant effluents subjected to drastic salinity reductions that lowered conductivities to <5 mS/cm were killed (Holt and Strawn 1977).

High salinities are also tolerated. Roessler (1970) collected pinfish at salinities as high as $43.8^0/_{00}$ in Buttonwood Canal, FL. According to Cameron (1969b), pinfish are found in water exceeding $70^0/_{00}$ in Baffin Bay, TX.

Incipient lethal dissolved oxygen concentration for pinfish is about 1.1 mg/l (Cameron 1969b). Oxygen consumption of pinfish per unit body weight was found to be higher than that of cyprinodontid and poeciliid fishes that are permanent salt-marsh residents (Subrahmanyam 1980). This relatively greater need for oxygen may explain why pinfish avoid shallow, hypoxic tidal pools (Subrahmanyam 1980). Subrahmanyam found that pinfish have a critical oxygen-tension level of 24 mm Hg. Water supersaturated with dissolved gases, such as in power plant effluents, has been shown to be hazardous to pinfish (Chamberlain and Strawn 1977). Pinfish can apparently detect oxygen saturation levels and respond by moving away from supersaturated conditions, when possible (Romanowsky and Strawn 1979).

Siltation apparently does not greatly affect pinfish; Ingle (1952) found individuals in the vicinity of an active dredge. Reid (1954) reported pinfish killed by a hurricane at Cedar Key, FL, in 1950, but whether death was caused by siltation, turbulence, salinity drop, or some other cause is not known.

Pinfish have been used extensively in pesticide testing. Schimmel et al. (1979) found that pinfish exposed to 2.4 μg/l EPN (O-ethyl-o-p-nitrophenyl phenyl phosphonothionate) bioconcentrated rapidly and reached apparent equilibrium in about 48 h; equilibrium concentration in pinfish tissue was 1.7 mg/kg.

Bioconcentration studies using EPN indicated a bioconcentration factor of about 707 for extended exposure (Schimmel et al. 1979). When pinfish were no longer exposed to EPN they eliminated most of its residues in 4 d and virtually all in 8 d. Coppage and Matthews (1975) tested the effects of the organophosphate insecticide naled (1,2-dibromo-2,2-dichloroethyl dimethyl phosphate) on brain acetylcholinesterase activity in pinfish. Twenty-four-hour exposure to a nominal concentration of 75 μg/l naled killed 40-60% of the pinfish exposed, as did 48-h exposure to 55 μg/l, and 72-h exposure to 25 μg/l. Exposure to 15 μg/l for 96 h caused no mortality, although sublethal doses of naled were demonstrated to cause measurable changes in acetylcholinesterase activity. Coppage (1977) also found reduced brain acetylcholinesterase activity in pinfish exposed to carbamate pesticides.

Results of acute toxicity tests of several organochlorine compounds are compared in Table 2. Borthwick and Schimmel (1978) found that 48-h posthatch pinfish larvae were very sensitive to Na-PCP (sodium pentachlorophenate) (96-h LC_{50} = 38 μg/l) and Dowicide G (79% Na-PCP) (96-h LC_{50} = 66 μg/l). Hansen, Parrish, and Forester (1974) reported no deaths in pinfish subjected to 100 μg/l of Arochlor 1016 (a polychlorinated biphenyl) for 96 h, but a 42-d exposure to 32 μg/l caused significant mortality and liver tissue changes. A bioconcentration factor of as high as 17,000 was found for a 56-d exposure to 1 μg/l Arochlor 1016 (Hansen, Parrish, and Forester 1974). Pinfish avoided Arochlor 1254 concentrations of 10 mg/μl (Hansen, Schimmel, and Matthews 1974). Malathion in a concentration of 30 μg/l killed 60% of the pinfish tested by Cook et al. (1976), within 72 h. Cook and Moore (1976) found that specimens exposed to 75 μg/l malathion for 24 h retained no malathion, but did retain its metabolites mono-carboxylic acid malathion in the liver and di-carboxylic acid malathion in the gut. Bioconcentration of pesticides appears

Table 2.—Acute toxicity and bioconcentration factors of pesticides for 96-h tests of *Lagodon rhomboides*.

Compound	Test conditions	LC_{50} (μg/L) Nominal dose	Measured dose	Bioconcentration factor	Authors
Na-PCP (sodium pentachlorophenate)	$\bar{x}$ 25.0°C $\bar{x}$ 20.8‰	107.6	53.2	—[1]	Schimmel et al. (1978)
Chlordane	31.3°C 24.6‰	10.4	6.4	2,000-4,800	Parrish et al. (1976)
Lindane	22.5-25.0°C 21-23‰	—	30.6	218	Schimmel, Patrick, and Forester (1977b)
BHC	22.0-26.0°C 20-23‰	—	86.4	482	Schimmel, Patrick, and Forester (1977b)
Toxaphene	24.0-26.0°C 18.5-26.0‰	0.56	0.53	3,900	Schimmel, Patrick, and Forester (1977a)
Heptachlor (tech. grade 65%)	27.5-30.0°C 25.0-31.0‰	—	3.77	2,800-7,700	Schimmel et al. (1976)
Endosulfan	$\bar{x}$ 24.3°C $\bar{x}$ 16.4‰	0.44	0.30	1,299 (@0.15 μg/L) 1,046 (@0.26 μg/L)	Schimmel, Patrick, and Wilson (1977)
EPN	$\bar{x}$ 64 mm SL $\bar{x}$ 25.0°C $\bar{x}$ 28.8‰	—	18.3	744	Schimmel et al. (1979)

[1]Not given.

to be greater in the viscera than in edible tissues (Schimmel, Patrick, and Forester 1977b).

Heavy metal sensitivity of pinfish was examined by Whaling et al. (1976), who fed juveniles a diet of blue marlin axial muscles containing 15 ppm (wet weight) mercury. Test animals died beginning after 30 d of the high mercury diet and showed accumulation of mercury in the axial muscles, liver, kidney, heart, and brain. The LC_{50} of copper is 0.15 ppm for pinfish larvae (Engel et al. 1976). Larger pinfish subjected to copper by Cardeilhac and Hall (1977) became lethargic and stopped eating at concentrations of 6.2 ppm; longer exposure caused uncoordination, with deaths occurring about 10 h after copper addition began (concentration 7.2 ppm). Signs of distress stopped 17 h after copper concentration fell below 0.2 ppm. Effects of copper poisoning in pinfish include increased serum levels of urea nitrogen, alkaline phosphatase, sodium, and potassium; and increased levels of copper in the gills, liver, and kidneys (Cardeilhac and Hall 1977; Cardeilhac 1981). Electrolyte imbalance results from impaired osmoregulation and hemolysis (Cardeilhac and Hall 1977). Selenium toxicity was tested on pinfish by Ward et al. (1981); LC_{50} for 96-h was 4.4 mg/l at 30‰ and 22°C.

Pinfish have been shown to tolerate fairly high concentrations of bleached kraft mill effluent (BKME) from paper production (Stoner and Livingston 1978). Young specimens maintained in aquaria with BKME added showed increased ventilation rates, lowered condition factors, lowered moisture and lipid contents, higher protein contents, and reduced capacity for food conversion. Avoidance of BKME is elicited at concentrations of 0.06% or higher (Livingston et al. 1976; Lewis and Livingston 1977). Avoidance of residual chlorination is 0.02-0.4 mg/l chlorine (Cripe 1979).

Effects of other pollutants on pinfish have also been reported. Daugherty (1951) found pinfish to be relatively resistant to chemicals associated with oil-well drilling. Hall et al. (1978) found the LC_{50} of No. 2 fuel oil to be <1.8 mg/l after 4 h, and 0.58 mg/l after 96 h. Stone et al. (1975) reported that pinfish were not harmed by exposure to tires used in artificial reefs. Hoss et al. (1974) found that sediments from Charleston Harbor, SC, were harmful in high concentrations to larval pinfish, possibly due to ammonia toxicity.

Red tides have been reported to kill pinfish on the west coast of Florida (Gunter et al. 1948; Springer and Woodburn 1960).

Radiation exposure LD_{50} for pinfish postlarvae is 2,083 rads for 50 d at 18°C (White and Angelovic 1966).

See 3.66 and 3.44.

3.33 Competitors

Stoner and Livingston (1984) studied competition between pinfish and spottail pinfish, *Diplodus holbrooki*, and concluded that the two species, though sympatric, do not compete directly for food because of differences in morphology. Food habits of pinfish and sheepshead, *Archosargus probatocephalus*, are similar (Hildebrand and Cable 1938), but competition may be reduced by different food size selection in adults, and different habitat utilization between juvenile sheepshead and adult pinfish (Darnell 1958). Food habits of pinfish from Card Sound, FL, show a strong similarity to those of the mojarras *Eucinostomus gula* and *E. argenteus* (Brook 1977). Juvenile pinfish may avoid competition with anchovies in canals at Marco Island, FL, by switching to benthic feeding habits (Kinch 1979). Competition with juveniles of other species is reduced because juvenile pinfish enter shallow water several months before the young of most other species (Kinch 1979). Of adult fish, only pinfish were found to consume attached algae in Marco Island canals (Kinch 1979).

See 3.41 and 3.42.

3.34 Predators

Predators on pinfish include fish: Sandbar shark, *Carcharhinus plumbeus* (formerly *C. milberti*), (Hildebrand and Schroeder 1928); ladyfish, *Elops saurus*, (Darnell 1958); gulf toadfish, *Opsanus beta*, (Reid 1954); southern hake, *Urophycis floridana*, (Reid 1954); red drum, *Sciaenops ocellatus*, (Peterson and Peterson 1979); spotted seatrout, *Cynoscion nebulosus*, (Moody 1950; Carr and Adams 1973); weakfish, *C. regalis*, (Merriner 1975); sailfish, *Istiophorus platypterus*, (Voss 1953); southern flounder, *Paralichthys lethostigma*, (Darnell 1958); marine mammals: Spotted dolphin, *Stenella plagiodon*, (Siebenaler and Caldwell 1956; Springer 1957); and birds: Eastern brown pelican, *Pelecanus occi-*

dentalis carolinensis, (Howell 1932); magnificent frigate bird, *Fregata magnificens rothschildi*, (Howell 1932; Springer 1957); and double-crested cormorant, *Phalacrocorax a. auritus*, (Scattergood 1950).

3.35 Parasites, diseases, injuries, and abnormalities

A list of parasites known from pinfish appears in Table 3. Hall and Iversen (1967) found pinfish from the southwest coast of Florida with cysts caused by the myxosporidean parasite *Henneguya lagodon*. About 5% of individuals caught in summer in Mississippi estuaries have lesions, possibly of bacterial origin (Overstreet and Howse 1977). Stott et al. (1980) found a protozoan parasite on the testicular capsule of at least one pinfish off Louisiana.

Table 3.—Parasites from *Lagodon rhomboides*. (From Caldwell 1957, table 7.)

Species	Location on fish	Author
Phylum: Protozoa		
Class: Sporozoa		
Order: Myxosporidia	external	Causey *in* Caldwell (1957)
Phylum: Platyhelminthes		
Class: Trematoda		
Order: Monogenea		
Pseudohaliotrema carbunculus	gills	Hargis (1955)
Order: Digenea		
Leprocreadium ovalis	intestine	Manter (1931)
Lepidauchen hysterospine	intestine	Manter (1931)
Distomum monticellii	intestine	Linton (1905)
D. appendiculatum	?	Linton (1905)
D. vitellosum	intestine	Linton (1905)
D. pyriforme	?	Linton (1905)
D. corpulentum	?	Linton (1905)
Diastomum sp.	?	Linton (1905)
Cymbephallus vitellosus	?	Linton (1940)
Class: Cestoidea		
Scloex polymorphus	intestine	Linton (1905)
Rhynchobothrium sp.	visceral cysts	Linton (1905)
Otobothrium crenacolle	cysts	Linton (1905)
Tetrarhynchus bisulcatus	cysts	Linton (1905)
Phylum: Nematoda		
Ascaris sp.	body cavity on viscera	Linton (1905)
Phylum: Acanthocephala		
Echinirhynchus pristis	intestine	Linton (1905)
E. sagittifer	on viscera	Linton (1905)
Phylum: Arthropoda		
Class: Crustacea		
Subclass: Copepoda		
Caligus praetextus	external	Causey *in* Caldwell (1957)
Caligus praetextus	?	Bere (1936)
Hatschekia linearis	gills	Pearse (1953)
Lernathropus amplitergum	gills	Pearse (1953)
Lernaeenicus polyceraus	external	Causey *in* Caldwell (1957)
Argulus funduli	?	Bere (1936)
A. varians	?	Bere (1936)
Subclass: Malacostraca		
Agathoa medialis	gills	Pearse (1953)

3.36 Physiology, biochemistry, etc.

Composition of pinfish from Campeche Bank was analyzed by Korzhova (1965), who found that 45.2% of the total weight of the fish was skin and flesh and 26.8% was head. Flesh contained 19.3% protein, 4.1% fat, 1.4% ash, and 74.9% water, and had a caloric content of 107 cal/g.

Caloric content of pinfish from Beaufort, NC, increases with age (Adams 1976a, c) (Table 4). Thayer et al. (1973) determined that the caloric content of pinfish from the Newport River estuary, NC, varied seasonally, with the high fall value of adults due to prespawning lipid production; carbon and lipid contents of adults were higher than for juveniles. Caloric content of pinfish from the Newport River estuary was measured at 4.665 cal/mg dry weight by Angelovic et al. (1969).

Conversion efficiency of laboratory-held pinfish fed ad libitum was determined to be 4.42-10.47% of wet weight, 8.57-18.13% of dry weight, and 7.98-17.70% of total organic nitrogen (Darnell and Wissing 1975). Nitrogen absorption efficiency was 86.73-97.32%.

Table 4.—Caloric content by size class of *Lagodon rhomboides* collected at Beaufort, NC. (Data from Adams 1976a, c.)

Fish size (mm SL)	*N*	Caloric content (cal/mg ash-free dry wt.)	SD
12-16	8	5.36	—
20-50	48	5.46	0.25
51-85	87	5.54	0.27
>89	39	5.91	0.34

Blood characteristics of pinfish from Redfish Bay, TX, were reported by Cameron (1969b, 1970). Average erythrocyte counts were $2.657 \pm 0.387 \times 10^7$ cells/mm^3 in late summer through winter, with mean cell diameter $9.3 \times 6.6\ \mu$. Mean corpuscular hemoglobin was 28.6 pmg/cell with a mean blood hemoglobin of 7.59 ± 0.72 g/100 ml (gram percent). Clotting time was 8 s. Hematocrit averaged $32.9 \pm 3.0\%$ for all seasons, with a blood oxygen capacity of 7.78 ml O_2/100 ml blood. In laboratory experiments, as temperature was increased, hemoglobin concentration and red cell number increased and hematocrit and mean erythrocyte volume decreased. Small increases in hematocrit and hemoglobin were noted in response to increased salinity. Vigorous exercise caused a decrease in blood volume. Comparison with other fish species indicates that blood characteristics of pinfish are similar to those of other moderately active species (Cameron 1969b). Cameron and Wohlschlag (1969) examined effects of anemia on respiration of pinfish and found that tolerance of low oxygen levels was not clearly related to hemoglobin concentration; reserve capacity of hemoglobin may be important in meeting unusual demands of migration or escape. Large individuals do not withstand high temperatures as well as smaller ones due to differences in oxygen consumption (Wohlschlag and Cech 1970).

Oxygen consumption was measured at 0.096 ml/g per h for an 11.6 g pinfish and 0.071 ml/g per h for a 13.5 g individual by Subrahmanyam (1980). Pinfish die at critical oxygen tension of 24 mm Hg, which may be due to inability to respire at lower oxygen tensions.

Pinfish are capable of tolerating freshwater (5mmol Na), if sufficient calcium is present (10mmol) (Carrier and Evans 1976). Pinfish have a mechanism for extracting sodium from low-sodium environments providing that calcium concentration is high enough to prevent passive permeability of sodium into the surrounding water (Carrier and Evans 1976). Chloride excretion in pinfish takes place largely through chloride-secreting cells on the

gill epithelium (Hootman 1978; Hootman and Philpott 1978, 1979).

Chloride-secreting cells are of importance in branchial electrolyte regulation at both high and low environmental salinities (Hootman and Philpott 1978). The number and size of the cells increase in pinfish adapted to high salinities (Hootman 1978). Hootman and Philpott (1979) examined the subcellular structure of chloride-secreting cells of pinfish and found them to be the major site of activity of the electrolyte transport enzyme Na^+, K^+-ATPase; activity of this enzyme increased when pinfish were transferred from brackish water to seawater. Additional studies on this enzyme, including microscopy of the pinfish pseudobranch, were presented by Dendy (1972). Farmer and Evans (1981) examined chloride extrusion by pinfish gill tissues and found a transepithelial potential of +0.73 ± 0.0075 mV in isolated gills in Ringer's solution and +9.61 ± 1.83 mV in seawater. Transepithelial potential of gills in an intact pinfish was +1.21 ± 0.32 mV in Ringer's and +12.94 ± 2.21 mV in seawater. Chloride efflux was measured at 789 ± 71 μmol/g per h in an isolated gill and 1,764 ± 587 μmol/g per h in the intact animal in Ringer's solution, and 1,385 μmol/g per h in an isolated gill and 3,422 ± 916 μmol/g per h in the intact animal in seawater.

Pinfish lymphocytes have been shown to respond differently at different temperatures of acclimation (Abruzzini et al. 1979, 1982; Clem et al. 1981). Temperature apparently affects lymphocyte mitogenic responses and plasma membrane fluidity and may thus affect pinfish immunity (Abruzzini et al. 1982).

See 3.32 and 3.36.

3.4 Nutrition and growth

3.41 Feeding

Pinfish are primarily benthic feeders with the exception of larvae and small juveniles, which feed higher in the water column.

Larval pinfish locate food visually (Peters and Kjelson 1975). Studies conducted in the Newport River estuary, NC, by Kjelson et al. (1975) and Kjelson and Johnson (1976) investigated feeding of pinfish larvae. Larvae 15-19 mm TL were found to feed most actively when there was little or no current; specimens from nearshore contained more copepods than ones collected in channels. Prey size increased with larva size, with 16-20 mm TL larvae preferring copepods of about 600 μm. Peak feeding activity occurrred during the day, with maximum gut fullness at 1200 h (Kjelson et al. 1975; Peters and Kjelson 1975; Kjelson and Johnson 1976) (Figs. 6, 7) and a maximum feeding rate of 26 copepods/h. Daily food consumption was found to be 38 copepods/fish per d (about 3.5% of total body weight), or 0.63 cal/fish per d, by Kjelson et al. (1975), and 92 copepods/fish per d, or 1.3 cal/fish per d, by Kjelson and Johnson (1976). Gut capacity of an 18 mm TL larva was about 37 650-μm copepods (Kjelson et al. 1975). Evacuation rates of larvae appear in Table 5.

Juveniles feed as planktivores when very small, shifting to larger benthic organisms and algae as the fish increase in size (Kinch 1979; Livingston 1980; Stoner 1980c). Young are often found feeding among seagrass blades (Stoner 1979b). Breder (1962) observed juveniles apparently picking parasites from *Mugil cephalus*. Feeding is diurnal; guts are empty at night (Peters and Kjelson 1975; Brook 1977; Stoner and Livingston 1984). Daily ration for juveniles is about 9.5% of the total dry body weight per day (Peters and Kjelson 1975). Food evacuation rates (Fig. 8) and evacuation rates as a function of temperature (Fig. 9) were studied by Peters and Kjelson (1975).

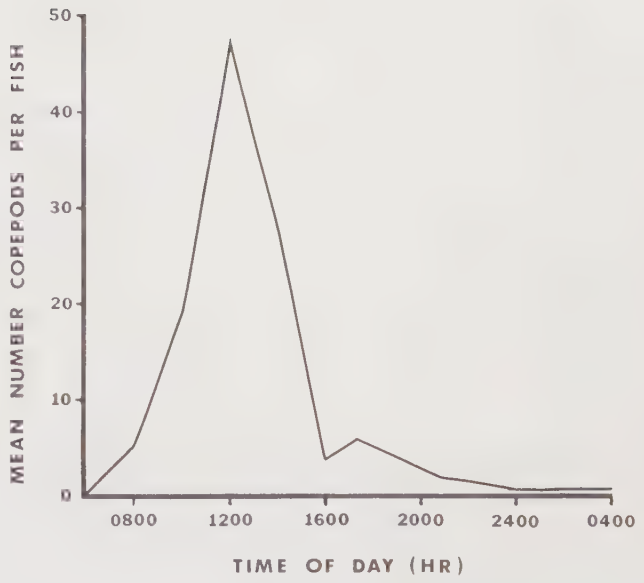

Figure 6.—Diel cycle of digestive tract contents in larval *Lagodon rhomboides* at 15°C based upon the geometric mean of the number of copepods per fish ($n = 10$ fish per sampling time). (From Kjelson and Johnson 1976, fig. 2.)

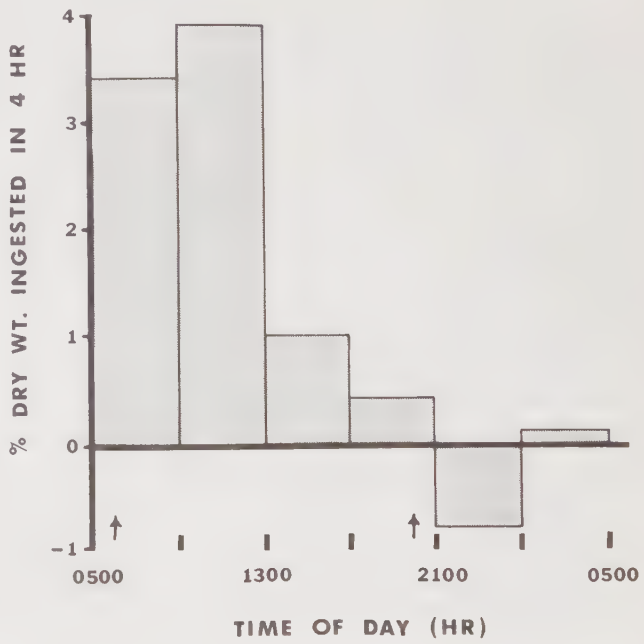

Figure 7.—Diel cycle of food consumption (% dry body weight per 4-h period) by *Lagodon rhomboides*. Negative value indicates net egestion for the period. Arrows indicate sunrise and sunset. (From Peters and Kjelson 1975, fig. 6.)

Table 5.—Evacuation rate equations for larval *Lagodon rhomboides* from the Newport River estuary, NC.

Size of larvae (mm TL)	Equation[1]	Temperature (°C)	Authors
15-18	$Y = 1.30-0.18t$	12	Kjelson and Johnson (1976)
15-20	$Y = 0.94-0.10t$	16	Kjelson et al. (1975)
13-19	$Y = 0.68-0.08t$	17	Kjelson et al. (1975)

[1]Where $Y = \log_{10}$ (1 + mean no. copepods/larva), t = hours since feeding.

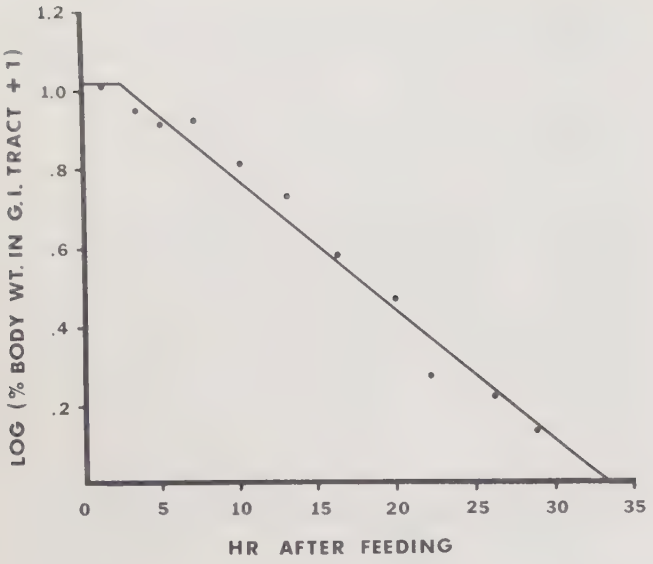

Figure 8.—Gastrointestinal evacuation of commercial food by *Lagodon rhomboides* at 24°C. Each point is the geometric mean of five observations. Log_{10} (% body weight in G.I. tract + 1) = 1.037 − 0.033 (X − 2), where X = hours since feeding, lag = 2 h, R^2 = 0.97. (From Peters and Kjelson 1975, fig. 4.)

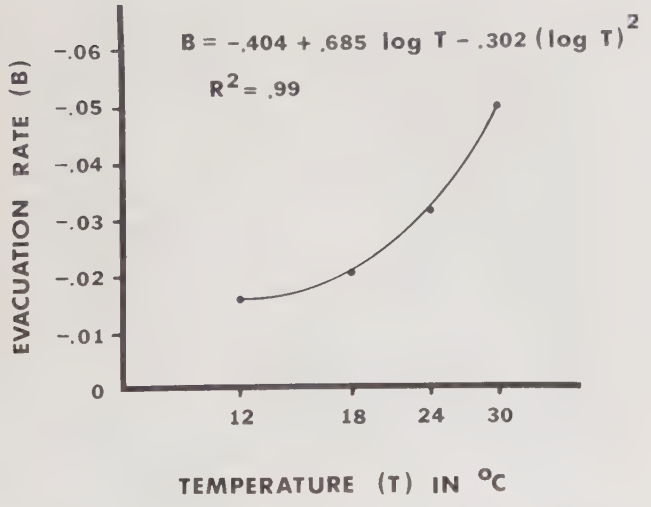

Figure 9.—Food evacuation rates in *Lagodon rhomboides* as a function of temperature. Evacuation rate is the net change in the weight of the gut contents per hour. (From Peters and Kjelson 1975, fig. 5.)

Large juveniles and adults often graze on vegetated bottoms (Darnell 1958), usually not venturing beyond seagrass-covered habitats in shallow water (Stoner 1979b). Epifaunal invertebrates are nipped or scraped from hard substrates such as rocks and pilings (Darnell 1958; Hastings 1972; Stanford 1974; Hastings et al. 1976). Teeth are well adapted for grazing (Gunter 1945), large food items being bitten or nibbled and small items being consumed whole (Caldwell 1957). Transition to herbivory involves microepiphyte nibbling followed by seagrass grazing (Stoner 1980c; Stoner and Livingston 1984). Individuals may occasionally rise to the surface to feed (Caldwell 1957; Hastings 1972). Large pinfish sometimes rotate to a lateral position and bite sections out of *Syringodium* blades (Stoner and Livingston 1984).

Food is located visually and olfactorily (Stanford 1974; Stoner and Livingston 1984). Carr and Chaney (1976) found that feeding behavior could be elicited by a mixture of five amino acids plus betaine. Extracts of shrimp, crab, clam, oyster, whelk, mullet, and sea urchin also produced feeding response in pinfish in decreasing order of potency (Carr et al. 1976).

Pinfish are generalist feeders (Stoner 1980c), though individuals may be selective at certain times. Stoner (1979b) studied selective feeding of pinfish on amphipods and concluded that high seagrass density caused increased selectivity for certain amphipod species. Like juveniles, adults feed diurnally (Caldwell 1957; Darnell 1958; Stanford 1974; Adams 1976c; Hastings et al. 1976). Feeding individuals may form aggregates, often by size group, with largest individuals most aggressive and least prone to feeding in large groups (Stanford 1974; Stanford and Schwartz 1977). Fish assume an angle of 25° from the horizontal while feeding (Stanford 1974; Stanford and Schwartz 1977). When in seagrass beds, most feeding is done somewhat above the substrate; individuals seldom approach the sediment between plants except at night (Stoner 1979b). Foraging behavior is a complex function of predator, prey, and habitat characteristics (Stoner 1982).

Pinfish are voracious feeders and notorious bait stealers (Caldwell 1957; Stanford 1974; Hoese and Moore 1977). Hansen (1970) reported heaviest feeding in summer and early fall at Pensacola, FL, with reduced feeding during the spawning season. Peters et al. (1976) found that temperature affects feeding rate much more than salinity. In the laboratory, subsistence feeding rate was determined to be 5.75% of body weight per day (Darnell and Wissing 1975). Food consumption at a single meal is greatest at 24°C and falls off rapidly by 30°C (Peters et al. 1974). Evacuation rates of commercial food were calculated by Peters et al. (1974) (Table 6). Evacuation rate of natural foods is approximated by the relationship $Y = 0.388 - 0.0323\ X$, where Y = (1+ % body weight in gastrointestinal tract), and X = hours since capture (Peters et al. 1974). Food in the gastrointestinal tract was estimated at 1.4% of the total body weight (Peters et al. 1974). Peters and Hoss (1974) used a radioactive tag to estimate evacuation time of pinfish at 32.7 h.

The alimentary tract, described by Stoner and Livingston (1984), is composed of a short esophagus, a thick walled, but highly distendable stomach with internal convolutions, and a tubular, unconvoluted intestine. The undistended stomach is a small, subcylindrical outpocketing of the alimentary tract and is pointed posteriorly. The intestine runs about half way to the vent, makes one loop anteriorly to the base of the pylorus, and returns to the vent in one to three short convolutions. The total gut length increases with body length from 0.76 times SL in 15 mm SL juveniles to a maximum of 1.52 times SL in 80 mm SL juveniles, then decreases to about 1.1 times SL in adults.

See 3.42 and 4.6.

Table 6.—Regression equations of evacuation rate of *Lagodon rhomboides* fed commercial food at varying temperatures in the laboratory. (Data from Peters et al. 1974.)

Temperature (°C)	Equation[1]
12	$Y = 0.9417 - 0.0168\ (X\text{-}12)$
18	$Y = 0.8719 - 0.0216\ (X\text{-}6)$
24	$Y = 1.0368 - 0.0335\ (X\text{-}2)$
30	$Y = 1.0363 - 0.0528\ (X\text{-}1)$

[1]Where Y = log_{10} (1 + percent body weight in gastrointestinal tract), X = hours since feeding.

3.42 Food

Pinfish are basically omnivores, but have been shown to undergo several transitions of food habits with growth. Although accepting a wide range of food items during a lifetime, pinfish may be fairly selective feeders in certain areas and at certain stages of growth. Prey-size selection depends on size of the fish and density of the prey (Nelson 1979a). Prey choice varies with seagrass blade density (Stoner 1979a, 1980a) and species of seagrass (Stoner 1982). Spatial variations of food habits within pinfish size classes are related to standing crops of prey species (Stoner 1979a).

Larvae and postlarvae (<20 mm SL) are planktivorous, feeding mainly on copepods (Carr and Adams 1973; Kjelson and Johnson 1976; Adams 1976c; Livingston 1980; Stoner 1980c; Stoner and Livingston 1984). Larvae examined by Kjelson et al. (1975) contained 99% copepods (by number): Harpacticoida 32%, *Centropages* 28%, *Acartia* 13%, *Temora* 3%, others 23%. At Marco Island, FL, Kinch (1979) found a transition from copepod feeding in 11-15 mm SL individuals, to amphipods, oligochaetes, and polychaetes in 16-20 mm SL individuals (Table 7). Pinfish 11-15 mm SL show maximum dietary breadth in late spring and lowest in winter (Stoner 1979a).

Small juveniles (approximately 20-35 mm SL) are primarily carnivorous, feeding on shrimp postlarvae, amphipods, mysids, harpacticoid copepods, invertebrate eggs, and other animal matter (Reid 1954; Carr and Adams 1973; Nelson 1979a; Livingston 1980; Stoner 1980c; Stoner and Livingston 1984) (Table 8). Small pinfish (25-33 mm SL) consume more amphipods per unit time than larger (48-67 mm SL) fish (Stoner 1982). Gunter (1945) found razor clam shells and plant material in 15.0-28.5 mm TL specimens from the Texas coast. At Marco Island, FL, Kinch (1979) found a predominance of polychaetes, oligochaetes, mysids, and amphipods in stomachs of small juveniles. Adams (1976c) reported that 3-5 mm SL specimens from Beaufort, NC, contained copepods and detritus.

Large juveniles (approximately 36-80 mm SL) are basically omnivorous, with the broadest diet of any size-group of pinfish (Darnell 1958; Livingston 1980; Stoner 1980c). Stoner (1979a) found that individuals 16-80 mm SL showed maximum dietary breadth in mid-summer and lowest in late fall and winter. Both plants and macrobenthic animals become increasingly prevalent in the diet. Carr and Adams (1973) categorized 36-60 mm SL pinfish from Crystal River, FL, as herbivores on microepiphytes and 61-80 mm SL fish as omnivores on epiphytes, shrimp, and fish. Kinch (1979) noted an increase in algae in the diet of individuals 30 mm SL from Marco Island and concluded that the increase was due to an increase in algae in the habitat during the time when juveniles were reaching 30 mm SL.

Benthic organisms become increasingly important in the diet of large juveniles as the fish attain larger sizes. Darnell (1958) reported that small invertebrates were the main food of 40-74 mm (type of length measurement unspecified) pinfish from Lake Pontchartrain, LA, with amphipods (*Corophium* spp., *Cerapus* sp., various gammarids) making up the major portion of the diet. Benthic copepods, isopods, and chironomid larvae and pupae were also found in the stomachs examined. Nelson (1979a) reported that small pinfish at Beaufort, NC, selected the amphipod *Elasmopus levis* over *Melita appendiculata* and *Ampithoe longimana*. Hansen (1970) found that juveniles <76 mm SL from Pensacola, FL, preferred crustaceans and polychaetes (Table 9). An analysis of stomach contents of 47-87 mm TL juveniles from the Newport River estuary, NC, produced 56 ± 1% animal material, 8 ± 7% phytoplankton, 26 ± 5% unidentified detritus, and 10 ± 3% vascular plant detritus, by volume (Peters and Kjelson 1975); an analysis of food consumed by 50-60 mm TL specimens showed the food composition to be 24.7 ± 4.5% sand, 49.5 ± 4.6% ash, and 10.6 ± 1.0% nitrogen, with an energy content of 5.31 ± 0.15 cal/mg ash-free dry weight. Adams (1976c) reported that pinfish 65-70 mm SL were more omnivorous than smaller fish, feeding less on detritus and more on polychaetes, larval fish, and plant material (Table 10). Stoner (1980c) and Stoner and Livingston (1984) also found juveniles (36-80 mm SL) to be omnivorous, with about 30% of the diet made up of plants (mostly epiphytes)

Table 8.—Percent frequency of occurrence of food items in *Lagodon rhomboides* from Cedar Key, FL. (From Reid 1954, table 4.)

Food item	Size class (mm SL)		
	15-50	51-100	101-128
Copepods	29.4	65.6	25.0
Amphipods	52.9	18.7	18.7
Shrimps	58.8	37.7	25.0
Crabs	—[1]	9.4	—
Mollusks	—	12.5	18.7
Fish	—	3.1	—
Plant detritus	—	3.1	—
Organic detritus and mud	—	34.4	—

[1]Not present.

Table 7.—Percentage dry weight of stomach contents of *Lagodon rhomboides* from Marco Island, FL, canals. (From Kinch 1979, table 4.)

Food item	Size class (mm SL)							
	11-15	16-20	21-30	31-35	36-40	41-50	51-60	61-70
Oligochaetes	32	30	17	5.5	4	—[1]	—	—
Polychaetes	—	13	59	—	17	31	83	34
Nematodes	3	4	—	—	—	—	—	—
Copepods	45	21	2	8	1	—	4	—
Amphipods	13	22	22	35	—	—	5	—
Mysids	—	—	—	34	4	—	—	—
Unident. crustaceans	—	—	—	—	4	—	—	—
Fish eggs	—	—	—	—	—	5	—	—
Algae	—	—	—	12	70	64	—	65
Organic debris	7	10	—	—	—	—	8	1
Mud	—	—	—	5.5	—	—	—	—

[1]Not present.

Table 9.—Percentage of total food volume contributed by different items in *Lagodon rhomboides* from lower Pensacola estuary, FL, by season, 1963-65. (From Hansen 1970, table 1.)

	Size class (mm SL) and season							
	<76				76-173			
Food item	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
Crustaceans	58.3	2.8	21.7	44.8	8.7	4.6	5.6	24.9
Polychaetes	17.3	1.0	2.9	43.4	8.0	4.0	4.0	19.4
Chordates	3.1	1.5	1.1	10.8	12.5	2.0	2.9	31.3
Vegetation	4.6	87.2	66.5	0.9	21.9	66.4	56.6	23.1
Sand	12.9	6.7	6.6	0.0	44.4	18.9	29.5	0.2
Other[1]	3.8	0.8	1.2	0.1	4.5	4.1	1.4	1.1

[1]Includes brachiopods, bryozoans, chaetognaths, echinoderms, mollusks, and nemerteans.

Table 10.—Annual average percentage by weight of food items consumed by *Lagodon rhomboides* in eelgrass beds near Beaufort, NC. (From Adams 1976c, table 1.)

Food item	Juveniles (n = 118)	Adults (n = 97)
Polychaetes	3.9	10.5
Scallops	—[1]	1.7
Other bivalves	—	0.2
Bittium (gastropod)	—	0.5
Calanoid copepods	19.6	9.5
Harpacticoid copepods	1.7	0.3
Gammarid amphipods	10.9	7.2
Caprellid amphipods	6.3	9.5
Isopods	0.6	0.5
Palaemonetes (shrimp)	3.6	0.8
Hippolyte (shrimp)	3.0	0.7
Crabs	0.7	—
Juvenile and larval fish	—	0.8
Filamentous algae	7.1	9.8
Eelgrass	10.5	7.7
Eelgrass seeds	—	5.8
Detritus	30.4	27.8
Other	1.7	6.5

[1]Not present.

and about 70% of macrobenthos (amphipods, small shrimp, harpacticoid copepods); amphipods were the preferred food of juveniles at Apalachee Bay, FL, with *Cymadusa compta*, *Lembos* sp., *Elasmopus levis*, and *Paracaprella tenuis* most often selected (Stoner 1979b). Nelson (1979b) also reported amphipods a dominant food item of pinfish at Beaufort, NC. Livingston (1980) reported the bivalve mollusk *Brachidontes exustus* fairly common in 81-120 mm SL pinfish. In Florida Panhandle salt marshes, Subrahmanyam and Drake (1975) found plants, detritus, sand, insects, and nereid polychaetes in the stomachs of 55-110 mm SL pinfish, with an increasing tendency towards carnivorism with growth.

Adults are omnivorous and quite broad in their food habits (Caldwell 1957; Adams 1976c); variation in food habits with space is a function of food availability and habitat structure (Stoner 1980c). Greatest dietary breadth occurs in spring and summer and lowest in fall (Stoner 1979a). Darnell (1958) reported that small benthic invertebrates and zooplankton were found in all size classes of pinfish examined from Lake Pontchartrain, LA, with algae becoming more important as fish increased in size; filamentous green algae (*Cladophora* sp., *Oedogonium*, *Rhizoclonium*, *Spirogyra*) were most abundant in stomachs examined, but vascular plants (*Vallisneria spiralis* and possibly *Ruppia maritima*) were also consumed. Weinstein et al. (1982) found evidence of cellulose digestion in pinfish.

Macrobenthic animals such as crabs (*Callinectes sapidus*, *Rithropanopeus harrissi*), shrimps (*Palaemonetes* sp., *Macrobrachium ohione*), and fishes (*Gobiosoma bosci*) were also important in the diets of pinfish examined by Darnell (1958). A change from dominance of microbenthic animals to vegetation was noted at about 90 mm SL (Darnell 1958) (Fig. 10). Stoner (1980c) and Stoner and Livingston (1984) reported that at over 80 mm SL, pinfish from Apalachee Bay grew increasingly herbivorous, containing at least 50% plant material; specimens >100 mm SL contained 10% animal matter. Livingston (1980) found that individuals >120 mm SL from Apalachee Bay were almost strictly herbivorous on the seagrasses *Syringodium filiforme* and *Thalassia testudinum*, though invertebrates were sometimes eaten.

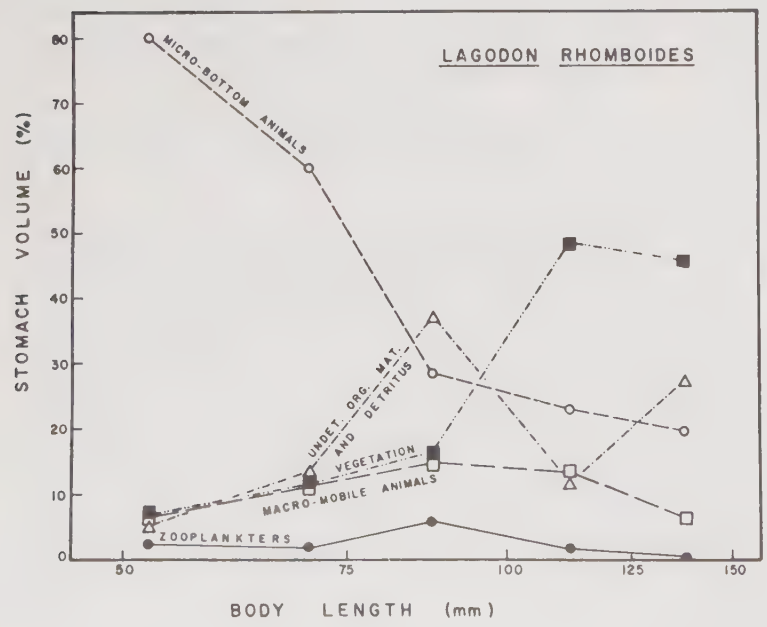

Figure 10.—Ontogenetic food progression of *Lagodon rhomboides* in Lake Pontchartrain, LA. Type of body length measurement is unspecified. (From Darnell 1958, fig. 14.)

Several other authors have reported on the food habits of pinfish. Hildebrand and Schroeder (1928) listed vegetable debris, crustaceans, mollusks, and annelids from pinfish collected in Chesapeake Bay. Reid (1954) reported copepods, shrimps, amphipods, and crabs as the most frequently occurring food items in adults from Cedar Key, FL. Large amounts of plant material were found in specimens from Tampa Bay, FL (Springer and Woodburn 1960); some individuals contained primarily, or only, *Halodule* (*Diplanthera*) or *Enteromorpha*. At Pensacola, FL, Hansen (1970) found that vegetation (diatoms, filamentous algae, vascular plants) was the major portion of the diet of pinfish by volume, with sand, crustaceans, polychaetes, fish, and cephalochordates making up significant portions. At Crystal River, FL, adults are mainly carnivorous on shrimp and fish (*Eucinostomus* and *Menidia*) (Carr and Adams 1973). Hastings (1972) observed pinfish feeding on ctenophores on one occasion in St. Andrew Bay, FL. Brook (1977) found plant material, polychaetes, copepods, amphipods, tanaids, isopods, shrimps, fish, and mollusks in pinfish from Card Sound, FL. Adams (1976c) found detritus to be the most important food of adults in the Newport River estuary, NC, followed by polychaetes. Specimens from the Newport River estuary examined by Hyle (1976) contained 17.4% vegetation, 17.3% polychaetes, 14.8% crustaceans, and 6.9% fishes, by volume. Crustaceans and polychaetes were major food items in the summer and fall, and filamentous algae were the main components in winter and spring (Hyle 1976); food diversity was greatest in summer and fall, and mean stomach fullness was lowest in winter. Pinfish from Chesapeake Bay examined by Orth and Heck (1980) (75-110 mm SL) contained detritus, isopods, barnacles, mollusks, pipefish, eelgrass, and *Palaemonetes* spp. Pollutants can significantly alter trophic units of pinfish (Livingston 1980).

The order of preference of foods chosen in laboratory experiments by Stanford (1974) was: Shrimp, polychaetes, fish, and vegetation. Other feeding experiments by Stanford and Schwartz (1977) showed medium and large pinfish selecting polychaetes first 80% of the time.

3.43 Growth rate

Growth rate of pinfish has been reported by several authors (Table 11, Fig. 11). Kilby (1955) found two size classes present in January at Cedar Key, FL; small individuals (13-20 mm SL) reached 45-80 mm SL by the end of the year, and larger individuals (50+ mm SL) reached 100+ mm SL by July. Growth rate determinations by Caldwell (1957) were similar to those of Kilby (1955), with the largest fish 100-110 mm SL and the smallest

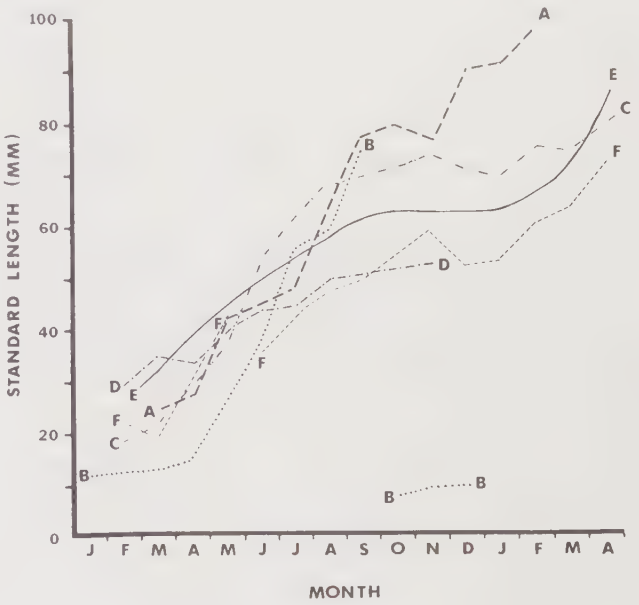

Figure 11.—Growth curves of *Lagodon rhomboides* from length-frequency data for the following studies: A. Hellier 1962, Laguna Madre, TX; B. Hildebrand and Cable 1938, Beaufort, NC; C. Caldwell 1957, Cedar Key, FL; D. Hoese and Jones 1963, Redfish Bay, TX; E. Cameron 1969b, Redfish Bay, TX; F. Reid 1954, Cedar Key, FL. (From Cameron 1969a, fig 3.)

Table 11.—Comparative monthly mean standard lengths (mm) for age-0 *Lagodon rhomboides* collected on the west coast of Florida.

Study	Year collected	Feb.	Apr.	June	Aug.	Oct.	Dec.
Springer and Woodburn (1960)[1]	1957	—[2]	—	—	—	78.6	76.5, 17.5
(Tampa Bay)	1958	19.9	28.8	51.3	62.6	78.1	88.3, 16.8
Reid (1954)[1,3]	1950	—	—	42.0	50.0	60.0	53.0, 15.0
(Cedar Key)	1951	22.0	30.0	—	—	—	—
Caldwell (1957)[1]	1953	19.9	30.4	53.2	67.9	71.3	71.2, 14.3
(Cedar Key)	1954	17.2	19.7	—	—	-	—
Grimes (1971)[1,4]							
(Crystal River—affected)[5]	1969	—	39.0	53.0	60.0	67.0	78.0
(Crystal River—nonaffected)[5]	1969	18.0	19.0	35.0	—	—	—
Grimes and Mountain (1971)[1]							
(Crystal River—affected)	1970	15.0	38.3	50.9	70.7	79.1	70.3, 13.6
(Crystal River—nonaffected)	1970	—	21.0	50.5	68.4	75.6	75.2, 13.7
Stoner and Livingston (1984)[3]	1971-79	17	22	43	50	62	—
(Apalachee Bay)							

[1]The newly spawned year class is included in December.

[2]No data.

[3]Figures are means estimated from graph.

[4]Statistical comparison of annual growth of fish from thermally affected and nonaffected areas revealed no significant difference (Grimes 1971).

[5]The terms affected and nonaffected refer to thermal additions from a power plant.

65-70 mm SL by the end of the first year of growth. Caldwell (1957) found that growth slowed after the first year, with a mean increase of about 50 mm SL in the second year and about 45 mm SL in the third year. Stoner and Livingston (1984) reported Apalachee Bay, FL, pinfish to reach 63 mm SL by November of the first year, and 95 mm SL by May of the second year. In Florida Panhandle salt marshes, Zilberberg (1966) reported that pinfish increased in length from 18 mm SL in March to 52 mm SL in June. Hansen (1970) found that fish entering their third year of life at Pensacola, FL, had a length of 127 mm SL at scale annulus formation. Daily growth increments were 0.19 mm/d for age-0 fish, and 0.12 mm/d for age-I fish, with a seasonal growth breakdown of:

	Spring	*Summer*	*Fall*	*Winter*
Age 0	0.32 mm/d	0.23	0.01	—
Age I	0.32	0.21	−0.04	−0.02

(Hansen 1970). Using scale annuli, Hyle (1976) back-calculated lengths of pinfish of 103.6 mm SL at age I and 121.9 mm SL at age II in the Newport River estuary, NC; annulus formation took place in late April to early May.

Increases in weight in pinfish were calculated by Cameron (1969b), based on data of other authors:

Author	*Area*	*Wt. at end of first yr. (g)*
Reid (1954)	Cedar Key, FL	4.3
Cameron (1969b)	Redfish Bay, TX	7.8
Caldwell (1957)	Cedar Key, FL	11.0
Hellier (1962)	Laguna Madre, TX	22.3

Stoner and Livingston (1978) found a mean growth rate of 1.90% increase in body weight per day in juvenile pinfish and a conversion efficiency of 44.6%.

Growth rate is dependent on temperature, increasing at higher water temperatures. Growth slows or stops in the coldest months of the year (Hildebrand and Cable 1938; Caldwell 1957) and is most rapid in the summer when water warms (Moe and Martin 1965; Zilberberg 1966). Cameron (1969b) noted that the period of maximum growth of pinfish also corresponds to the period of maximum plant growth on Texas flats and hypothesized that the slower growth rate of pinfish in Texas compared with Florida is due to colder winter water temperatures and poorer winter food supplies. Experiments by White and Angelovic (1973) indicated that of temperature, salinity, and solar radiation, temperature had the greatest effect on growth rate. Peters et al. (1976) found lowest growth efficiencies at intermediate salinities. Growth rate and food conversion efficiency are reduced at increased concentrations of bleached kraft mill effluent (Stoner and Livingston 1978). Pinfish cultured in cooling lakes of a Texas power plant (Holt and Strawn 1977) grew at < 0.19 g/d. Caged pinfish held in the power plant effluent grew at an average of 0.7 g/d (Chamberlain and Strawn 1977).

The relationship of standard length to total length of pinfish was calculated by Cameron (1969a):

$$SL = 0.78\ (TL).$$

Scale radius is related to standard length by the relationship:

$$Y = 0.1371 + 0.0251X \quad (r = 0.86, n = 56)$$

where Y is scale radius in millimeters and X is standard length in millimeters (Hyle 1976).

Length-weight relationships for pinfish have been prepared by several authors:

$$\log W = -4.3734 + 2.9136 \log L$$

where L is standard length in millimeters and W is body weight in grams (Caldwell 1957, Cedar Key, FL);

$$\log W = -4.353 + 2.903 \log L \quad (r = 0.99)$$

where L is standard length in millimeters and W is body weight in grams (Cameron 1969a, Redfish Bay, TX);

$$\log W = -5.708 + 3.561 \log L$$

where L is standard length in millimeters and W is body weight in grams (Hyle 1976, Newport River estuary, NC). Hoss (1974) determined length-weight relationships of larvae, juveniles, and adults from the Newport River estuary as:

$$W = 0.0098\ TL^{3.17} \quad (n = 315)\ \text{(juveniles and adults)}$$
$$W = 0.0089\ TL^{2.84} \quad (n = 49)\ \text{(larvae)}$$

where TL is total length in millimeters and W is body weight in grams. Tabb and Manning (1961) plotted the relationship of body weight to fork length of pinfish from Florida Bay, FL (Fig. 12).

3.44 Metabolism

Because of their abundance and their hardiness in the laboratory, pinfish have been studied by many workers. Size (weight) of the fish, temperature, activity, season, salinity, and pollutants have been correlated to metabolism.

Postlarval pinfish were studied by Hoss et al. (1971) and Thayer et al. (1974) (Tables 12, 13), who found that oxygen consumption increased with increasing size of the fish and temperature. Thayer et al. (1974) calculated daily oxygen-consumption rates for postlarvae: 0.11 mg O_2/fish per d (Nov.-Dec.), 0.16 mg O_2/fish per d (Jan.-Mar.), and 0.28 mg O_2/fish per d (Apr.-May), with an average value of 0.18 mg O_2/fish per d over the 7-mo

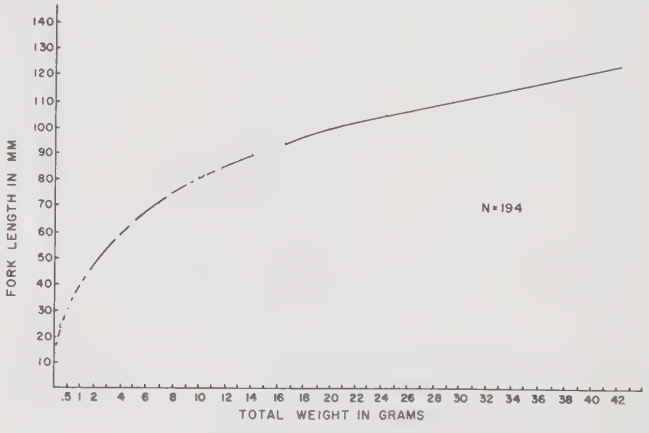

Figure 12.—Length-weight relationship of *Lagodon rhomboides* taken in Florida Bay at Flamingo, Everglades National Park, FL, in April 1959. (From Tabb and Manning 1961, fig. 8.)

Table 12.—Oxygen consumption coefficients for postlarval *Lagodon rhomboides*, for the relationship $Q = aW^k$, where Q is the rate of oxygen consumption in mg O_2/fish per h, W is wet weight of the fish in grams, and a and k are constants. (Data from Hoss et al. 1971.)

Temperature (°C)	W[1]	a	k	Q
15	0.03	0.586	0.910	2.4×10^{-3}
20	0.03	1.066	0.862	5.2×10^{-3}
25	0.03	1.002	1.002	3.0×10^{-3}

[1]Based on an average specimen of 30 mg.

Table 13.—Oxygen consumption coefficients for postlarval *Lagodon rhomboides*, for the relationship $Q = aW^k$, were Q is the rate of oxygen consumption in mg O_2/fish per h, W is wet weight of the fish in grams, and a and k are constants. (Data from Thayer et al. 1974.)

Month	Temperature (°C)	W	a	k	Q
Nov.-Dec.	10	0.019	0.393	1.122	4.6×10^{-3}
Jan.-Mar.	10	0.027	0.393	1.122	6.8×10^{-3}
Apr.-May	15	0.027	0.264	0.865	11.6×10^{-3}

period. Corresponding energy-consumption rates were 0.41 cal/fish per d (Nov.-Dec.), 0.16 cal/fish per d (Jan.-Mar.), and 1.04 cal/fish per d (Apr.-May), with an average of 0.68 cal/fish per d over the 7-mo period.

Peters and Kjelson (1975) found that 25 g pinfish held at 29°C respired 2.1% of their total energy content when unfed and 3.2% when fed to satiation once a day. Caloric intake was about 4.5% of total body energy each day; about 9.5% of body weight was consumed each day. Based on feeding studies at 16°C, 16-20 mm TL pinfish consumed 38 copepods/fish per d (3.5% of body weight), which were equivalent to 0.6 cal/fish per d (Peters and Kjelson 1975). Routine oxygen consumption measurements by Hettler and Hoss (unpublished data in Peters and Kjelson 1975) using 16-20 mm TL pinfish at 16°C, indicated an energy intake of 1.2 cal/fish per d. Excretion rate of ^{65}Zn was found to be unreliable in estimating pinfish metabolism (Hoss et al. 1978).

In general, oxygen consumption increases with increasing temperature, activity, and fish weight (Figs. 13-16, Tables 14-16). Adams (1976b) found that fish weight was more important than temperature in determining oxygen consumption. Hoss (1967) related respiration rate (Q) to fish weight in grams (W) using the equation:

$$Q = 0.335\ W^{0.719}.$$

Angelovic et al. (1969) found a similar relationship for 0.01-240.0 g pinfish from the Newport River estuary, NC:

$$Q = 0.303\ W^{0.752}.$$

Seasonal changes in respiration are due primarily to environmental temperature changes (Cameron 1969b), increasing in spring and summer and decreasing in fall and winter (Fig. 17, Tables 14, 15). Under normal circumstances, pinfish have fairly high respiration rates compared with temperate species (Wohlschlag and Cameron 1967).

Slightly polluted water may depress respiration rates (Wohlschlag and Cameron 1967; Kloth and Wohlschlag 1972). Although salinity has little effect on respiration under normal

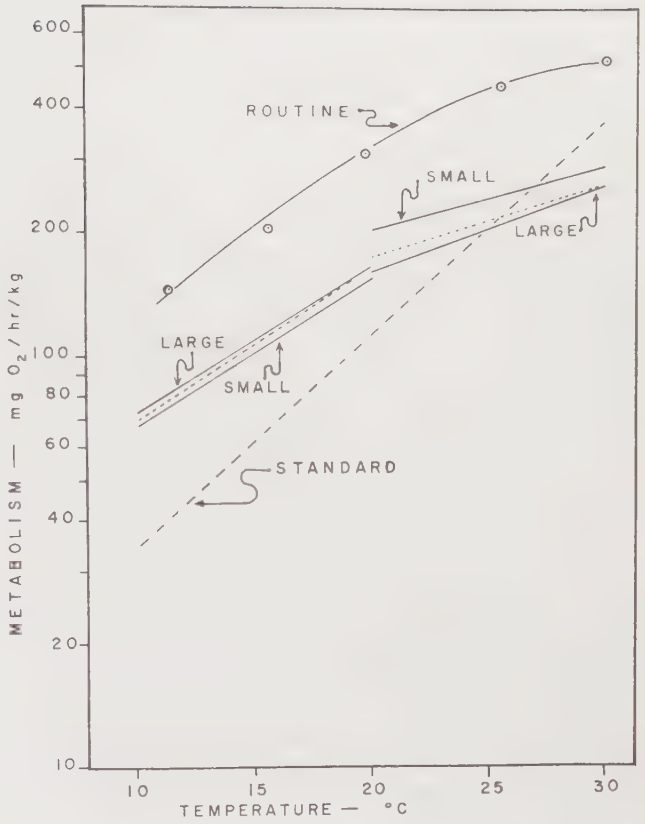

Figure 13.—Calculated oxygen consumption rates per kilogram for *Lagodon rhomboides* over two temperature ranges. Calculations are for small, large, and combined size groupings at zero swimming velocity. Data on routine and standard rates are from Wohlschlag et al. (1968). (From Wohlschlag and Cech 1970, fig. 1.)

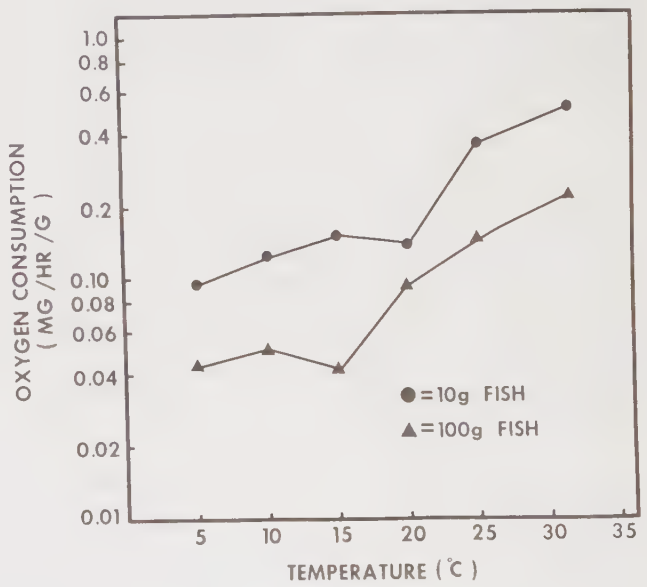

Figure 14.—Calculated oxygen consumption rates (mg/h per g) for 10 g and 100 g *Lagodon rhomboides* at various temperatures. Oxygen consumption values calculated by laboratory-determined metabolism-weight coefficients for the appropriate temperature. (From Hoss 1974, fig. 2.)

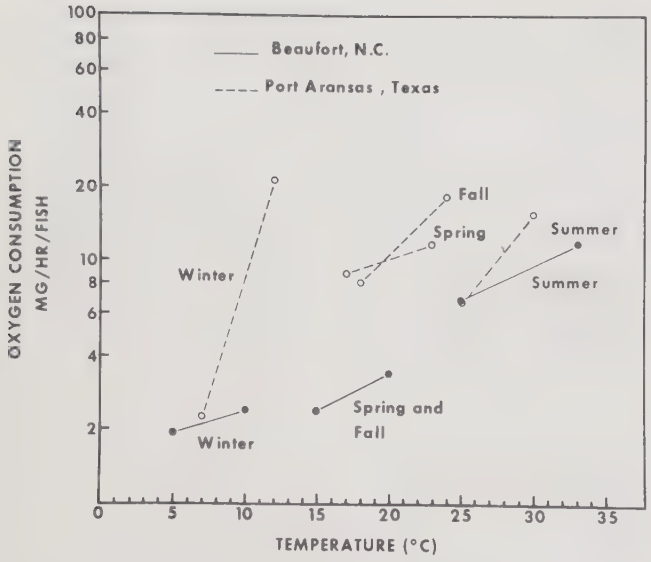

Figure 15.—Calculated oxygen consumption rates of 30 g *Lagodon rhomboides* from Texas and North Carolina at seasonal temperatures. Open circles represent data of Cameron (1969a) and closed circles those of Hoss (1974). (From Hoss and Peters 1976, fig. 1.)

conditions, Kloth and Wohlschlag (1972) found that large pinfish in high salinity ($45^0/_{00}$) water showed elevated metabolic rates in the presence of petrochemical pollutants.

3.5 Behavior

3.51 Migrations and local movements

Pinfish migrations consist primarily of inshore-offshore seasonal movements. Young begin to arrive on inshore grass beds in late fall or early winter (Hansen 1970). At Marco Island, FL, Kinch (1979) noted that juveniles moved into coastal canals in winter. Most pinfish leave shallow water in winter and move offshore (Hildebrand and Cable 1938; Gunter 1945; Joseph and Yerger 1956; Caldwell 1957; Hansen 1970; Hastings 1972; Moe 1972). Whether this offshore migration is in response to temperature or is for spawning, or both, is not clear. Pinfish abundance in

Table 14.—Oxygen consumption regression equations for several temperature ranges of *Lagodon rhomboides* inhabiting eelgrass beds near Beaufort, NC. (Data from Adams 1976b, table 4.)

Temperature range (°C)	N	Equation	r^2
13-15	8	$\hat{Y} = -1.42 + 0.91X_w + 0.08X_t$	0.99
15-18	18	$\hat{Y} = -0.24 + 0.64X_w + 0.01X_t$	0.94
19-22	27	$\hat{Y} = -0.55 + 0.60X_w + 0.04X_t$	0.88
23-26	23	$\hat{Y} = 0.53 + 0.70X_w - 0.01X_t$	0.94
26-28	27	$\hat{Y} = -1.45 + 0.67X_w + 0.06X_t$	0.97

Table 15.—Relationships of body weight, temperature, and swimming velocity (activity) to metabolism in *Lagodon rhomboides*. Coefficients fit the equation $\hat{Y} = a + bX_w + cX_t + dX_s$, where $\hat{Y}$ is the expected log mg oxygen consumed per hour, X_w is log weight in grams, X_t is temperature in °C, and X_s is swimming velocity in meters per minute. (Data from Wohlschlag et al. 1968.)

Season	Temperature (°C)	n	Coefficients a	b	c	d
Winter	10-20	18	−0.8909	0.9389	0.0287	0.0302
	20-30	18	−0.3397	0.7855	0.0178	0.0108
Spring	10-20	18	−1.0006	1.0043	0.0389	0.0089
	20-30	18	−0.2931	0.7889	0.0162	0.0049
Summer	10-20	30	−1.5114	1.0321	0.0379	0.0326
	20-30	24	−0.6441	0.8183	0.0183	0.0129
Fall	10-20	32	−1.0130	0.9715	0.0275	0.0143
	20-30	35	−0.4795	0.8381	0.0145	0.0118

Table 16.—Regression equations for metabolism of *Lagodon rhomboides* from Redfish Bay, TX, by season. (From Cameron 1969a, table 1.)

Season	N	Temp. range of X_t (°C)	Wt. range of X_w (log wet wt. in g)	Equation
Spring	24	17-23	0.183-1.543	$Y = -0.506 + 0.803X_w + 0.016X_t$
Summer	18	25-32	0.420-1.346	$Y = -2.026 + 0.732X_w + 0.071X_t$
Fall	19	18-24	0.462-1.179	$Y = -1.865 + 1.132X_w + 0.061X_t$
Winter	16	7-12	0.362-1.295	$Y = -2.366 + 1.191X_w + 0.135X_t$

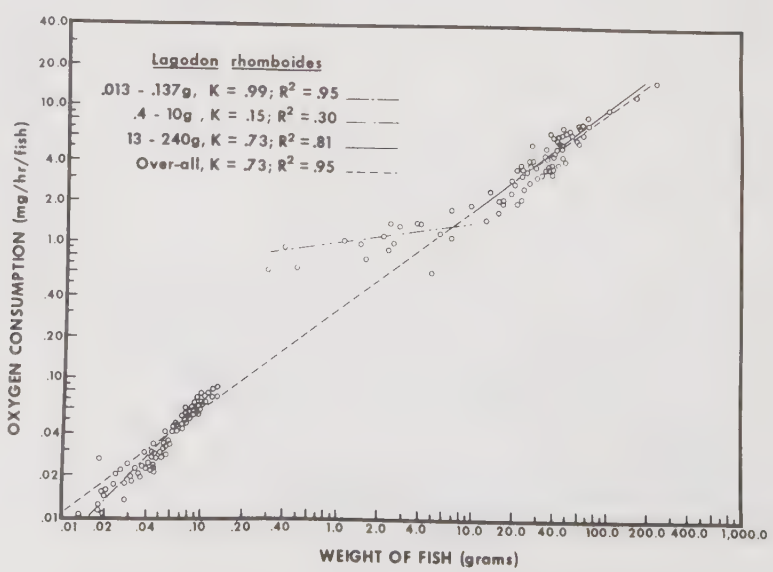
Lagodon rhomboides
.013 - .137g, K = .99; R² = .95
.4 - 10g, K = .15; R² = .30
13 - 240g, K = .73; R² = .81
Over-all, K = .73; R² = .95
OXYGEN CONSUMPTION (mg/hr/fish)
WEIGHT OF FISH (grams)

Figure 16.—Calculated regression of oxygen consumption on weight for pinfish between 0.3 and 67 g. Regressions for 0.013-0.137 g, 0.4-10 g, and 13-240 g fish are shown as well as overall regression equation. Each point represents data for one fish. (From Hoss and Peters 1976, fig. 2, based on unpublished data of Hoss.)

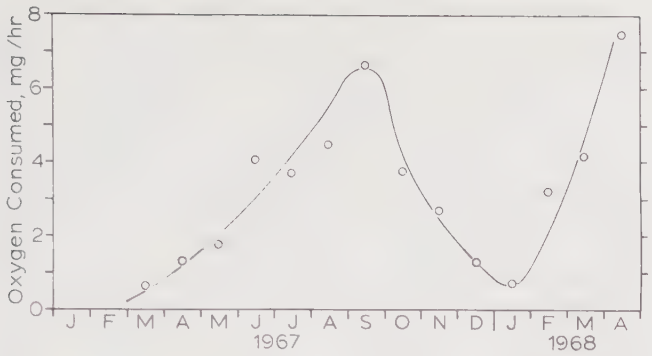

Figure 17.—Metabolic rate of the average size *Lagodon rhomboides* from Redfish Bay, TX, March 1967 to April 1968. (From Cameron 1969a, fig. 5.)

grassbeds is generally low in winter, rising again in spring (Cain and Dean 1976; Nelson 1979a; Stoner 1979a, 1980a; Orth and Heck 1980). Some small individuals may remain in shallow water year-round (Caldwell 1957); larger fish tend to seek deeper water (Cameron 1969a). Subrahmanyam (1980) reported that pinfish move into tidal creeks and pools at low tide to avoid shallow, hypoxic pools.

Rulifson (1977) measured swimming speed of juvenile pinfish (1.4-7.0 cm TL) at a maximum of 9.40 ± 0.215 body lengths/s, with an average burst speed of 9.42 ± 0.325 body lengths/s. Hettler (1978) determined a velocity of 10.8 body lengths/s for 3.7 cm mean FL pinfish at 27°C. Rulifson (1977) found a positive correlation between swimming speed and fish length and water temperature, with smaller fish more rheotactic than larger fish. Increasing salinity lowers swimming velocity (Kloth and Wohlschlag 1972); small pinfish decreased from 10.93 m/min (107.4 body lengths/min) at $20^0/_{00}$, to 8.92 m/min (75.0 body lengths/min) at $45^0/_{00}$; large pinfish decreased from 22.30 m/min (131.2 body lengths/min) at $20^0/_{00}$, to 8.64 m/min (54.3 body lengths/min) at $45^0/_{00}$.

See 2.3.

3.52 Schooling

Pinfish school primarily when young and during spawning migrations, but may also school during feeding. Hildebrand and Cable (1938) reported 12 to 16 mm TL young in schools with juvenile spot, *Leiostomus xanthurus*, and Atlantic croaker, *Micropogonias undulatus*, in quiet waters near jetties in Chesapeake Bay in winter. Subrahmanyam and Coultas (1980) also found a close association between pinfish and spot. Dense schools of juveniles were also reported in canals at Marco Island, FL, by Kinch (1979).

Large schools of pinfish may form before migrating offshore for spawning (Hansen 1970); other schools of age-I fish were seen at Pensacola, FL, returning to shallow water after the winter offshore migration. Schools of 1,000-2,000 ripe pinfish were observed at the surface well off the Mississippi coast by Springer (1957). Although Caldwell (1957) stated that pinfish do not usually form dense schools inshore, he pointed out that they may be so homogeneously abundant that definite schools are not distinguishable. Other authors (Stanford 1974; Randall and Vergara R. 1978) have mentioned large inshore aggregations. Feeding aggregations may be segregated by size, with largest individuals least likely to school (Stanford 1974). Some pinfish exhibit territoriality, which is usually shown by largest members of a school (Caldwell and Caldwell 1967). Territorial individuals chase other fish, including pinfish, away from their territory, often accompanied by clicking sounds produced by the teeth (Caldwell and Caldwell 1967).

3.53 Responses to stimuli

Small pinfish are more rheotactic than larger individuals (Rulifson 1977).

Romanowsky and Strawn (1979) found that pinfish held in cages in a thermal effluent stream of a power plant reacted to ambient light levels, gas saturation of the water, and pH. Pinfish are physoclists and probably detect and react to gas saturation through changes in swim bladder volume (Romanowsky and Strawn 1979). Gibbard (1979) observed extreme territorial and agonistic behavior in pinfish. In aquaria, pinfish have been observed to dive into the sand and disappear from sight when disturbed (Coen et al. 1981).

4 POPULATION

4.1 Structure

4.11 Sex ratio

Sex ratio is approximately 1:1. Pristas and Trent (1978) found no significant deviation from a 1:1 ratio in St. Andrew Bay, FL, though females predominated numerically.

4.13 Size composition

Numerous workers have published length-frequency data on pinfish (Reid 1954, Cedar Key, FL; Caldwell 1957, Cedar Key, FL; Springer and Woodburn 1960, Tampa Bay, FL; Hellier 1962, Upper Laguna Madre, TX; Hoese and Jones 1963, Redfish Bay, TX; Moe and Martin 1965, off Tampa, FL; Hansen 1970, Pensacola, FL; Grimes 1971, Crystal River, FL; Grimes and Mountain 1971, Crystal River, FL; Wang and Raney 1971, Charlotte Harbor, FL; Hyle 1976, Newport River estuary, NC; Stoner 1980c, Apalachee Bay, FL, see Fig. 18). Results indicate recruitment in winter and early spring with two main size-modes usually present in spring and summer.

4.2 Abundance and density

The pinfish is one of the most abundant fishes in shallow water through much of its range. Along the southeastern Atlantic coast of the United States, Angelovic et al. (1969) estimated pinfish abundance in the Newport River estuary, NC, at 1.6×10^6 fish in an area of 30 km^2, or approximately 0.05 fish/m^2. Adams (1976a) reported somewhat higher pinfish densities from the same general area, with adult abundance peaking in late summer and early fall (Table 17; Figs. 19, 20); abundance of postlarvae was greatest in spring and early summer as they moved into eelgrass beds. Approximately 64% of fish larvae captured by Thayer et al. (1974) in the Newport River estuary were pinfish. Bozeman and Dean (1980) reported that 31.7% of larval and estuarine fishes they caught in a South Carolina intertidal creek were pinfish. Schwartz (1964) reported that pinfish abundance in Isle of Wight and Assawoman Bays, MD, was highest in years with highest vegetation in the bays. They are not common in Chesapeake Bay (Orth and Heck 1980). Pinfish have also been reported abundant on live bottom on the continental shelf in the South Atlantic Bight (Barans and Burrell 1976).

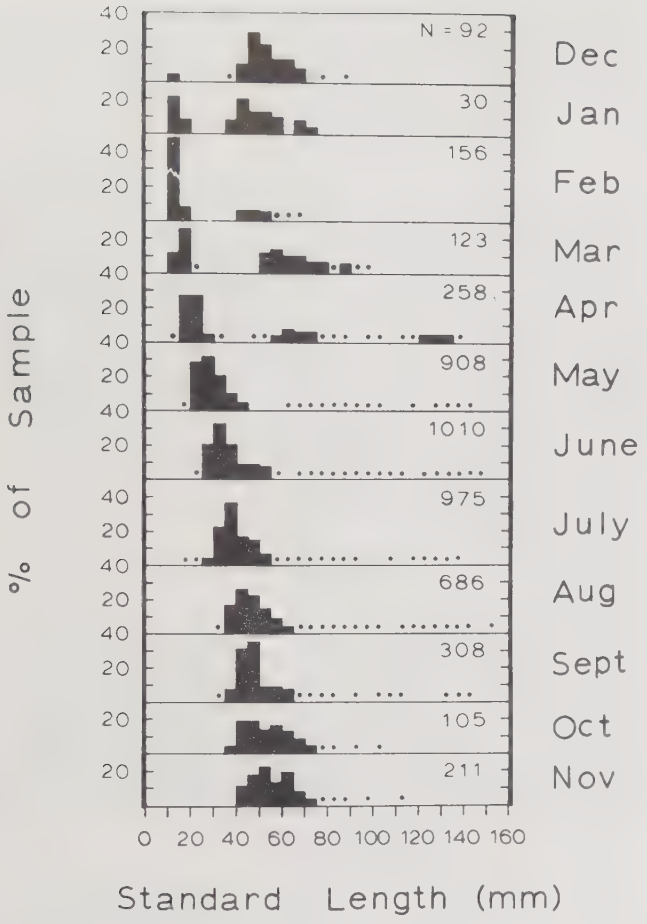

Figure 18.—Length-frequency distributions for *Lagodon rhomboides* collected in Apalachee Bay, FL, from December 1976 to November 1977. Dots indicate that <3.0% of the sample occurred in the size class. (From Stoner 1980c, fig. 5.)

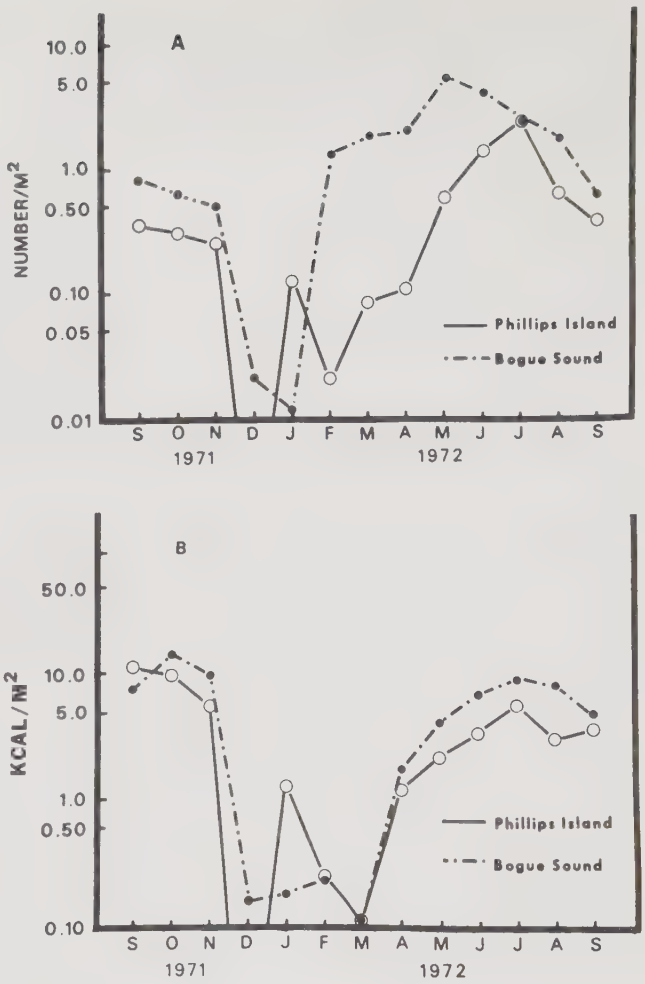

Figure 19.—Temporal distribution of A) numerical abundance (no./m²), and B) standing crop energy (kcal/m²), of *Lagodon rhomboides* from Phillips Island and Bogue Sound, NC. (From Adams 1976a, figs. 3, 4.)

Table 17.—Monthly population densities and energy contents of *Lagodon rhomboides* from Phillips Island (PI) and Bogue Sound (BS), NC, eelgrass beds. (From Adams 1976a, tables 3, 4.)

Year and month	Density (no./m²)		Energy (kcal/m²)	
	PI	BS	PI	BS
1971				
Sept.	0.39	0.82	11.62	7.51
Oct.	0.30	0.65	9.58	15.08
Nov.	0.25	0.49	5.50	9.60
Dec.	—[1]	0.02	—	0.13
1972				
Jan.	0.13	0.01	1.38	0.16
Feb.	0.02	1.32	0.24	0.21
Mar.	0.08	1.81	0.03	0.01
Apr.	0.11	1.94	1.15	1.89
May	0.63	5.22	2.13	3.99
June	1.33	4.07	3.42	6.84
July	2.07	2.39	5.75	8.52
Aug.	0.66	1.60	3.03	7.46
Sept.	0.37	0.65	3.77	3.93

[1]No data.

Along the Gulf of Mexico coast of the United States, pinfish have been reported as abundant in shallow water by numerous authors (e.g., Florida: Florida Bay, Tabb et al. 1962; Marco Island canals, Kinch 1979; Tampa Bay, Springer and Woodburn 1960; Crystal River, Grimes and Mountain 1971; Apalachee Bay, Stoner 1979a, 1980b, Stoner and Livingston 1984; St. Andrew Bay, Vick footnote 3, Naughton and Saloman 1978; Panhandle salt marshes, Subrahmanyam and Drake 1975; Louisiana: Barataria Bay, Fox and Mock 1968; Texas: entire coast, Hildebrand 1954; Galveston, Arnold et al. 1960; Redfish Bay, Hoese and Jones 1963; Upper Laguna Madre, Hellier 1962). Adults are usually most abundant inshore in late spring, summer, and fall (Gunter 1945; Caldwell 1957; Hoese and Jones 1963; Zilberberg 1966; Hansen 1970; Roessler 1970; Grimes 1971; Perret et al. 1971; Ogren and Brusher 1977; Naughton and Saloman 1978; Pristas and Trent 1978; Stoner and Livingston 1984), and least abundant inshore in the coldest months when they seek deeper water (Joseph and Yerger 1956; Grimes 1971). Postlarvae and juveniles appear to enter shallow water in winter and spring and may be quite abundant (Hansen 1970; Kinch 1979). Houde et al. (footnote 2)

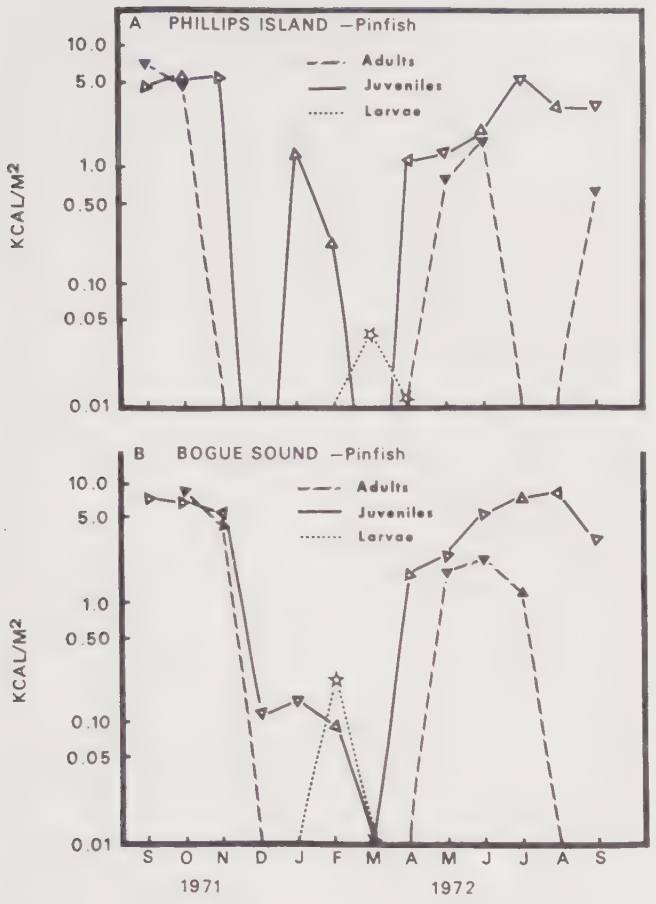

Figure 20.—Temporal distribution of the standing crop energy (kcal/m²) for three size-classes of *Lagodon rhomboides* from A) Phillips Island, and B) Bogue Sound, NC. (Adams 1976a, fig. 5.)

reported pinfish larvae among the 20 most-frequently captured species in the eastern Gulf of Mexico and estimated a maximum mean density of 11.7 larvae/10 m² column of water in the study area.

Offshore in the Gulf of Mexico, pinfish were reported common around man-made platforms off Panama City, FL, (Hastings 1972) and in trawl catches off Mississippi at 56-93 m (Franks et al. 1972). On the West Florida Shelf, pinfish occurred at 28.1% of trawl stations sampled in January 1978 (Darcy and Gutherz 1984). From Tampa Bay south to the Dry Tortugas, FL, pinfish made up 13.3% of the total fish catch in 9-35 m. On white shrimp grounds off the Texas coast, Cody et al.[4] reported catches of 981 g/h trawling (37.6 fish/h) and 40% frequency of occurrence in 1975-76, and 146 g/h trawling (6.3 fish/h) and 30% frequency of occurrence in 1976-77. On brown shrimp grounds in the northwestern Gulf, pinfish are most abundant in late winter (Chittenden and McEachran 1976).

Pinfish density on Campeche Bank in the southern Gulf of Mexico was estimated at 4.0 kg/ha in winter, 2.0 kg/ha in spring, 0.7 kg/ha in summer, and 1.3 kg/ha in fall by Olaechea and Sauskan (1974). Sauskan and Olaechea (1974) found pinfish most abundant at 30-50 m on the central Bank and estimated a mean abundance of 34,000 t for the entire Bank, with a possible annual harvest of 6-10,000 t. According to a MEXUS-GOLFO[5] report, pinfish are second in abundance only to *Haemulon aurolineatum* in night trawl catches on Campeche Bank. Hildebrand (1955) did not find pinfish to be common on shrimp grounds on Campeche Bank, but this may have been a different area of the Bank than that sampled by Sauskan and Olaechea (1974) and MEXUS-GOLFO (footnote 5).

See 2.3, 3.51, 4.33, and 4.6.

4.3 Natality and recruitment

4.31 Reproduction rates

Hansen (1970) reported 7,700-39,200 eggs/female (mean 21,600) for eight 111-152 mm SL pinfish from Pensacola, FL.

4.32 Factors affecting reproduction

Little is known regarding factors affecting reproduction. Caldwell (1957) speculated that pinfish spawning is probably affected by temperature, with adults seeking deeper water to achieve an optimum spawning temperature; water depth may be more important to spawning than distance offshore. Life history strategy seems to be adapted to seasonal patterns of productivity and abundance of prey and macrophyte species (Stoner 1979a).

4.33 Recruitment

Recruitment of young pinfish to shallow-water areas takes place in late fall, winter, and spring, with a peak in late winter and early spring. Thayer et al. (1974) estimated monthly larval recruitment to the Newport River estuary, NC, and found peak larval recruitment in February and March (Table 18). Hoss (1974) reported large numbers of 11-13 cm TL juveniles in the Newport River estuary in April, and Adams (1976a) found postlarvae moving into eelgrass beds in Bogue Sound, NC, in spring and early summer. In South Carolina intertidal creeks, Bozeman and Dean (1980) made largest catches of larvae and juveniles in February. Juvenile pinfish are especially abundant in Marco Island, FL, canals from November to April (Kinch 1979).

[4]Cody, T. J., K. W. Rice, and C. E. Bryan. 1978. Commercial fish and penaeid shrimp studies, northwestern Gulf of Mexico. Part II. Abundance and distribution of fauna on the white shrimp, *Penaeus setiferus* (Linnaeus), grounds off the central Texas coast. Coast. Fish. Branch Tex. Parks Wildl. Dep., Austin, Tex., P.L. 88-309 project 2-276-R, 39 p.

[5]MEXUS-GOLFO. 1979. Report on MEXUS-GOLFO Research Activities. Mimeogr., 11 p. Available at Southeast Fisheries Center, NMFS, NOAA, 75 Virginia Beach Dr., Miami, FL 33149-1099.

Table 18.—Estimated number of *Lagodon rhomboides* larvae entering Newport River estuary, NC, by month. (Data from Thayer et al. 1974.)

Month	No. of larvae	Mean cumulative larval density per m³
Nov.	1.5×10^6	0.05
Dec.	35.1×10^6	1.14
Jan.	17.5×10^6	1.99
Feb.	221.2×10^6	7.50
Mar.	248.8×10^6	16.86
Apr.	2.5×10^6	10.44
Total	526.6×10^6	

4.6 The population in the community and the ecosystem

Because of their abundance, pinfish are important as prey and predators, as well as being major contributors to community respiration, consumption, and production. Pinfish have frequently been studied by biologists investigating community trophic relationships and energy flows.

Pinfish are important as forage for larger recreationally and commercially important fish species, as well as for marine mammals and birds. As predators, pinfish occupy more than one trophic level (Hellier 1962). According to Tagatz (1976), pinfish are at the top of the dominant food chain in northern Gulf of Mexico grass beds: Turtle grass, *Thalassia testudinum*, → grass shrimp, *Palaemonetes vulgaris* → pinfish. Due to feeding selectivity, pinfish have been shown to play a role in the organization of faunal assemblages (Young et al. 1976; Young and Young 1977; Nelson 1978, 1979a, 1981; Stoner 1979b, 1980a, b, c; Nelson et al. 1982). Orth and Heck (1980) attributed the much higher epifaunal density of lower Chesapeake Bay, relative to North Carolina estuaries, to the scarcity of pinfish at the Chesapeake study site. Thayer et al. (1974) estimated that larval pinfish consumed about 10% of the zooplankton standing crop in the Newport River estuary, NC, between January and May. Weinstein et al. (1982) stated that pinfish are important consumers of plant material in warm temperate seagrass meadows.

The life history strategy of pinfish is adapted to seasonal patterns of macrophyte and prey abundance (Stoner 1980c). Stoner (1980c) noted that pinfish larvae appeared inshore at Apalachee Bay, FL, in mid-winter when calanoid copepods were at their peak of abundance. Similarly, juveniles (16-35 mm SL) appeared in grass beds in spring when amphipods and harpacticoid copepods were at their peak.

In the Newport River estuary, Angelovic et al. (1969) estimated an energy content of 47.6×10^6 cal for the entire 30 km² estuary (1.59 cal/m²), and a minimum pinfish respiration of 461×10^6 cal/d (15.4 cal/m² per d). If phytoplankton represents one-third of the total primary productivity of the estuary, and pinfish are secondary consumers in a food chain with 10% transfer efficiencies, then pinfish would require 8.7% of the total primary production for basic metabolism (Angelovic et al. 1969). Hoss (1971, 1974), also working in the Newport River estuary, calculated an average pinfish biomass of 23,433 kg/km² (2.34 g/m²) and an annual metabolic requirement of about 1×10^{11} cal/yr, or about 0.2% of the total primary production. Hoss (1974) found highest pinfish biomass and energy content in spring and summer and lowest in fall and winter; energy required for metabolism was highest in May-June due to rising temperature.

Adams (1976a, b), working in eelgrass beds in Bogue Sound and Phillips Island, NC, determined production and respiration values for juvenile and adult pinfish (Tables 19, 20); juveniles contribute more to the total community production and respiration than do adults, with highest values in summer. Consumption figures were also generally higher in juveniles (Table 21). In Phillips Island grass beds, pinfish contribution to total fish community respiration was 27%, biomass 47%, production 45%, and consumption 31%. In Bogue Sound grass beds the contribution to respiration was 63%, production 68%, and energy 64%. In both areas, pinfish were most abundant in summer and fall, making up 78% of the total fish standing crop at Phillips Island and 88% in Bogue Sound. Hellier (1962) also found peak production in summer in Laguna Madre, TX (Fig. 21). The role of pinfish in North Carolina eelgrass bed fish communities is shown in Figure 22.

Table 19.—Production (cal/m²) of *Lagodon rhomboides* in Phillips Island (PI) and Bogue Sound (BS) eelgrass beds, NC, September 1971-August 1972. Parentheses enclose negative values which were not included in totals. (From Adams 1976b, table 2.)

Year and month	Juveniles		Adults	
	PI	BS	PI	BS
1971				
Sept.	—[1]	—	1,260	788
Oct.	—	—	1,175	680
Nov.	—	—	—	(−428)
—				
1972				
Jan.	—	—	189	(−32)
Feb.	—	(−45)	—	—
Mar.	4	153	—	—
Apr.	59	801	702	500
May	572	3,312	860	243
June	1,904	4,046	—	495
July	1,980	2,344	—	—
Aug.	1,080	1,337	—	—
Total	5,599	11,993	4,186	2,706
% Total[2]	25.8	55.4	19.3	12.5

[1]No data.

[2]Percentage of production of all fish species caught at each study site.

Table 20.—Respiration (cal/m²) of *Lagodon rhomboides* in Phillips Island (PI) and Bogue Sound (BS) eelgrass beds, NC. (From Adams 1976b, table 3.)

Year and month	Juveniles		Adults	
	PI	BS	PI	BS
1971				
Sept.	—[1]	—	3,654	4,422
Oct.	—	—	1,570	3,054
Nov.	—	—	—	—
Dec.	—	—	—	12
1972				
Jan.	—	—	59	21
Feb.	—	—	—	7
Mar.	21	147	—	—
Apr.	89	1,252	412	680
May	1,041	4,937	722	697
June	3,375	8,916	—	664
July	4,893	7,383	—	—
Aug.	2,523	4,039	—	—
Sept.	—	—	260	—
Total	11,942	26,674	6,677	9,557
% Total[2]	17.1	46.1	9.6	16.5

[1]No data.

[2]Percentage of respiration of all fish species caught at each study site.

Other species commonly associated with pinfish at Cedar Key, FL, are: Pigfish, *Orthopristis chrysoptera*; silver perch, *Bairdiella chrysoura*; planehead filefish, *Monacanthus hispidus*; dusky pipefish, *Syngnathus floridae*; gulf pipefish, *S. scovelli*; and silver jenny, *Eucinostomus gula*, (Caldwell 1957). At open beach sites at Cedar Key, postlarval pinfish were found with large numbers of postlarval spot, *Leiostomus xanthurus*, (Caldwell 1957). Reid (1954) noted that, though pinfish are common on vegetated flats in summer at Cedar Key, they are largely replaced in shallow water in colder months by searobins, *Prionotus* spp.; puffers, *Sphoeroides* spp.; southern hake, *Urophycis floridana*; and flatfishes.

Table 21.—Summary energy budget (cal/m² per yr) and various efficiencies for *Lagodon rhomboides* in Phillips Island (PI) and Bogue Sound (BS) eelgrass beds, NC. (From Adams 1976b, tables 5, 6.)

	Production (*P*)	Respiration (*R*)	Consumption-Winberg (*C*)	Consumption-Bajkov (*C*)	*P/C*	*R/C*
Juveniles						
PI	5,599	11,942	21,922	22,500	0.25	0.55
BS	11,933	26,674	48,429	38,184	0.25	0.55
Adults						
PI	4,186	6,677	13,581	23,263	[1]0.18	0.49
BS	2,706	9,557	15,327	18,795	0.18	0.62

[1]Calculated using Bajkov consumption value.

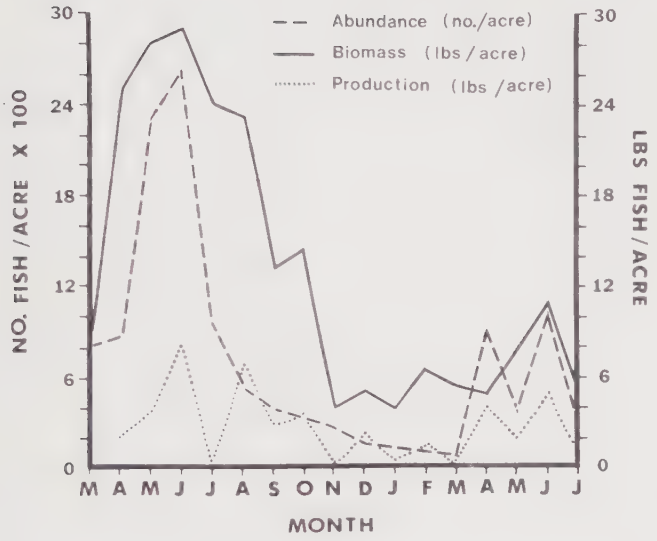

Figure 21.—Biomass, production, and number of *Lagodon rhomboides* from a drop-net quadrat in Laguna Madre, TX, March 1958-July 1959. Yearly production may be determined by totaling the production shown for each month. (From Hellier 1962, fig. 6.)

See 3.33, 3.34, 3.42, and 3.44.

5 EXPLOITATION

5.1 Fishing equipment

Pinfish are caught with trawls, gill nets, trammel nets, beach seines, traps, and hook and line (Caldwell 1957; Randall and Vergara R. 1978). Pinfish caught commercially for use as live bait are caught mainly in small baited or unbaited traps, with very small hooks on hook and line, or with cast nets or push nets. Pinfish used for crab bait or cat food are caught primarily in large bottom trawls (Caldwell 1957). Recreational fishermen catch most pinfish by using bait fished near the bottom. (Caldwell 1957).

5.2 Fishing areas

Pinfish are caught in shallow to moderately deep water from North Carolina to Texas (Randall and Vergara R. 1978) and on Campeche Bank off the Yucatan Peninsula (Sauskan and Olaechea 1974). Commercial shrimp and bottomfish trawlers in the Gulf of Mexico also catch pinfish incidental to the target

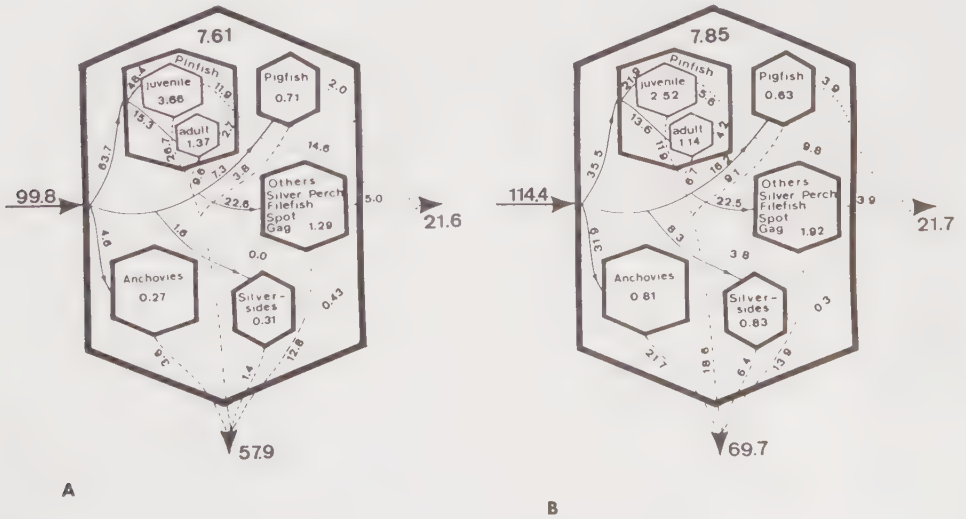

Figure 22.—Diagram of the energy flow (kcal/m²) of the fish community of A) Bogue Sound, and B) Phillips Island, eelgrass beds, NC. Large hexagon represents the total fish community and small hexagons represent fish populations; numbers inside hexagons are average annual standing crop (kcal/m²). Solid flow lines are food consumption, dashed lines oxygen consumption, and dotted lines production. (From Adams 1976b, figs. 2, 3.)

species. Recreational fishermen catch pinfish from shore, bridges, jetties, and boats throughout the range of the species, with vegetated areas producing largest catches.

See 2.1, 4.2, and 5.43.

5.3 Fishing seasons

Caldwell (1957) reported definite seasonality in pinfish abundance at Cedar Key, FL, with pinfish much more common inshore in spring and summer than in fall and winter. In St. Andrew Bay, FL, pinfish are caught by recreational fishermen most frequently from April to November, with a peak in October (Sutherland 1977), possibly because large specimens are more numerous late in the year. Because of their scarcity inshore in colder months, it is not economically feasible to fish for bait pinfish inshore in the winter (Caldwell 1957).

See 2.3.

5.4 Fishing operations and results

5.41 Effort and intensity

Little information on effort and fishing intensity is available. Anderson and Gehringer (1965) presented catch per unit effort data from off Cape Canaveral, FL (Table 22), and Anderson (1968) presented similar data from elsewhere along the southeastern Atlantic coast of the United States (Table 23). Both sets of data indicate low catch per effort, but neither study was conducted in areas or habitats known to have great numbers of pinfish and are thus not very useful in indicating true abundance along the coast.

Sutherland (1977) calculated average numbers of pinfish caught by recreational fishermen in St. Andrew Bay, FL. Catch per effort (fish per hour) for different bait types were: Squid 0.38, cut fish 0.03, live shrimp 0.03, dead shrimp 0.16.

5.42 Selectivity

Kjelson and Colby (1977) and Kjelson and Johnson (1978) studied the efficiency of bottom trawls at catching pinfish near Beaufort, NC. Using a trawl with a 6.1 m footrope, 19 mm bar mesh wings, and 6 mm mesh codend, Kjelson and Colby (1977) found recapture efficiencies of 0.69 for 38-85 mm (measurement unspecified) juvenile pinfish sampled immediately after release, 0.21 (day) to 0.23 (night) for 38-80 mm juveniles sampled after 2-3 d, and 0.50 (night) to 0.51 (day) for 90-157 mm adults. Kjelson and Johnson (1978), using the same trawl described above, estimated catch efficiencies of 0.48 for juveniles (53-79

Table 22.—Catch per unit effort of *Lagodon rhomboides* taken by trawling by MV *Launch 58* off Cape Canaveral, FL, by months for 2 yr. Gear used was a 22.9 m (75-ft) shrimp trawl towed at 3.7-5.6 km/h (2-3 kn). (From Anderson and Gehringer 1965, table 9.)

	Month												
	J	F	M	A	M	J	J	A	S	O	N	D	Total
No. fish/h	2.3	—[1]	1.0	0.6	5.0	—	0.2	1.5	1.2	1.0	8.0	6.5	2.1
% total catch	0.1	—	0.1	0.3	1.5	—	*[2]	0.1	*	*	0.1	0.2	0.1
Total no. fish	14	—	4	4	10	—	1	8	8	4	32	36	121

[1]No data.

[2]Less than 0.05.

Table 23.—Catch per unit effort of *Lagodon rhomboides* caught as by-catch of shrimp trawling along the southeastern Atlantic coast of the United States using a 22.9 m (75-ft) shrimp trawl towed at 3.7-5.6 km/h (2-3 kn). (Data from Anderson 1968, tables 2, 3, 4, 5, 8.)

	Month												
Location	J	F	M	A	M	J	J	A	S	O	N	D	Total
South Carolina, outside													
No. fish/h	—[1]	—	—	—	—	—	0.3	3.0	—	1.6	—	1.5	0.5
% total catch	—	—	—	—	—	—	*[2]	0.2	—	0.1	—	*	*
Total no. fish	—	—	—	—	—	—	2	15	—	8	—	8	33
Georgia, outside													
No. fish/h	0.1	0.8	—	—	34.2	3.6	15.4	—	—	0.9	1.8	0.5	4.4
% total catch	*	0.1	—	—	3.8	0.5	1.4	—	—	0.1	0.1	*	0.3
Total no. fish	1	30	—	—	752	64	462	—	—	26	35	13	1,383
Georgia, inside													
No. fish/h	0.1	—	—	*	—	0.1	0.7	*	—	—	—	—	0.1
% total catch	*	—	—	*	—	*	*	*	—	—	—	—	*
Total no. fish	1	—	—	1	—	3	21	2	—	—	—	—	28
Florida, outside													
No. fish/h	1.6	—	0.7	0.6	4.0	—	2.1	3.6	0.8	0.6	4.3	4.2	1.9
% total catch	0.1	—	*	0.1	1.5	—	0.2	0.2	*	*	0.1	0.1	0.1
Total no. fish	14	—	4	4	12	—	29	40	8	4	32	36	183
All stations combined													
No. fish/h	0.3	0.4	0.1	0.1	9.8	1.0	6.2	0.6	0.1	0.5	1.4	1.0	1.8
% total catch	*	*	*	*	1.0	0.1	0.4	*	*	*	0.1	*	0.1
Total no. fish	16	30	4	5	764	67	514	57	8	38	67	57	1,627

[1]No data.

[2]Less than 0.05.

mm FL) and 0.49 for adults (93-116 mm FL). Gill net mesh-size selectivity of pinfish was estimated to be: Mean FL (cm) ≅ 2.978 × stretched-mesh size (cm) (Trent and Pristas 1977).

5.43 Catches

Pinfish are quality food-fish, though their small size limits their commercial importance. They are sometimes marketed locally as panfish (Caldwell 1957) and are said to produce a high-grade oil (Hildebrand and Cable 1938); pinfish were sometimes shipped with menhaden to Beaufort, NC, for reduction to scrap and oil or fish meal. Potential use of pinfish as fish meal was also mentioned by Beaumariage (1968) and Randall and Vergara R. (1978). Pinfish are also caught for use as bait and are important catches of recreational and subsistence fishermen.

Accurate catch figures are difficult to obtain because separate statistics for pinfish are not usually reported (Caldwell 1957; Randall and Vergara R. 1978). Pinfish were of some commercial importance in the 19th Century; Goode (1884) reported that pinfish were highly prized for food and were salted or iced for shipment to market. Many were brought into Key West alive (Jordan 1884). Hildebrand and Schroeder (1928) reported pinfish landings of 454 kg (1,000 lb), worth $40, from Chesapeake Bay in 1922. Average weight of marketed fish was 0.15 kg (Hildebrand and Schroeder 1928). In 1935, pinfish landings in North Carolina were 81,650 kg (180,000 lb), and in Florida, 14,060 kg (31,000 lb) (Hildebrand and Cable 1938). Anderson and Power (1955) reported pinfish catches of 443,984 kg, valued at $32,812, from Florida and North Carolina combined in 1952.

Pinfish are not of major commercial importance today, though they do enter industrial bottomfish catches in the north-central Gulf of Mexico (Roithmayr 1965) and are used as pet food and as commercial blue crab bait (Caldwell 1957). They are sometimes killed in great numbers during commercial fishing operations directed at other species and are often a nuisance to shrimpers and gill-netters because of their sharp spines and their tendency to become tangled in nets. Pinfish made up 2.8% by weight of fish discarded by North Carolina shrimp trawlers from June to August 1970 (Wolff 1972) and 0.46% of trawl-caught fish in the South Carolina shrimp fishery in nearshore waters from May 1974 to August 1975 (Keiser 1976). Sauskan and Olaechea (1974) estimated annual commercial pinfish catch on Campeche Bank at 6,000-10,000 t. Pinfish are commonly caught and sold as live or cut bait, and are popular bait for red drum, *Sciaenops ocellata*; spotted sea trout, *Cynoscion nebulosus*; tarpon, *Megalops atlanticus*; snook, *Centropomus* spp.; and groupers (Caldwell 1957; Hastings 1972).

Although sometimes scorned as bait stealers, pinfish provide considerable sport to recreational fishermen (Caldwell 1957; Arnold et al. 1960). In East Lagoon near Galveston, TX, three quarters of all fish caught on hook and line are pinfish (Arnold et al. 1960). At Cape Canaveral, FL, the pinfish is the second most common sport fish, with the average fish weighing 0.11 kg (Anderson and Gehringer 1965). Recreational fishermen catch pinfish from bridges, piers, banks, boats, and in the surf. Sutherland (1977) reported that, in St. Andrew Bay, FL, most were caught from fixed platforms. Anderson and Gehringer (1965) found greatest numbers caught from bridges and causeways, with highest total pinfish catches taking place in fall (Table 24). U.S. Department of Commerce (1980) figures of recreational pinfish catches indicate most are caught from man-made structures or from small boats.

Table 24.—Estimated sport fishery catch of *Lagodon rhomboides*, Cape Canaveral area, FL, by season for March-October, 1963. (Data from Anderson and Gehringer 1965, tables 24, 26, 28, 30, 33, 35, 37, 39.)

Location		Spring	Summer	Fall	Total
South section,	No.	14,975	35,749	59,778	110,502
bridges and causeways	kg	1,698	4,054	6,779	12,531
South section,	No.	487	1,054	795	2,336
ocean piers	kg	55	119	29	203
South section,	No.	10,727	18,576	4,652	33,955
Port Canaveral, inside	kg	1,216	2,107	527	3,850
South section,	No.	—[1]	376	—	376
Port Canaveral, outside	kg	—	171	—	171
North section,	No.	3,438	16,122	3,441	23,001
banks	kg	389	1,830	384	2,603
North section,	No.	31,752	16,744	14,880	63,376
bridges	kg	3,601	1,898	1,687	7,186
North section,	No.	1,124	232	1,900	3,256
surf	kg	128	25	215	368
North section,	No.	4,228	3,328	56,822	64,378
boats	kg	479	377	6,443	7,299
Total	No.	66,731	92,181	142,268	301,180
	kg	7,566	10,581	16,064	34,211

[1]No catch reported.

Estimated total numbers of pinfish caught by recreational fishermen in 1979, by region, were as follows: North Atlantic, <30,000; Mid-Atlantic, <30,000; South Atlantic, 3,770,000; Gulf of Mexico, 9,070,000; total 12,811,000 (U.S. Department of Commerce 1980). In the South Atlantic region, catches by state were: North Carolina, 569,000; South Carolina, <30,000; Georgia, <30,000; Florida (east coast), 3,141,000; and in the Gulf, catches by state were: Florida (west coast), 7,858,000; Alabama, 213,000; Mississippi, 32,000; Louisiana, 30,000; and Texas 937,000. Of the total recreational pinfish catch recorded, 32.1% were caught in inland (sheltered) waters, 28.3% were caught in ocean waters <4.8 km (3 mi) offshore, 5.6% were caught in ocean waters over 4.8 km offshore, and 34.0% were from unknown localities.

7 POND FISH CULTURE

Female pinfish have been artificially induced to mature ova by injecting the fish with hormones, such as pituitary luteinizing hormone of mammalian origin, and human chorionic gonadotropin (Cardeilhac 1976; Schimmel 1977). Schimmel (1977) reported high variability in the response to hormonal injection. Eggs have been stripped and artificially fertilized (Cardeilhac 1976).

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